LECTURES

THE GRADUATE SCHOOL ANNOUNCES ITS SECOND LECTURE SERIES
FOR THE SCHOOL YEAR 1954 - 55

PROGRESS IN SCIENCE

JANUARY 19.......SIGNIFICANCE OF PROGRESS IN CHEMISTRY TO AGRICULTURE

Dr. Reid T. Milner, Head
Department of Food Technology
University of Illinois

FEBRUARY 2.......SIGNIFICANCE OF PROGRESS IN THE SOCIAL SCIENCES TO AGRICULTURE

Dr. M. E. Benedict
Professor of Agricultural Economics
Division of Agricultural Economics
University of California

FEBRUARY 9.......SIGNIFICANCE OF PROGRESS IN PHYSICS AND ATOMIC ENERGY TO AGRICULTURE

Dr. Sterling B. Hendricks, Head Chemist
Soils and Plant Relationships
Soil and Water Conservation Research Branch
Agricultural Research Service

FEBRUARY 16.......SIGNIFICANCE OF PROGRESS IN FOOD PRODUCTION TO AGRICULTURE

Dr. Frank A. Vorhes, Jr., Chief
Division of Food
Food and Drug Administration
Department of Health, Education and Welfare

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TIME: 4:00 p.m.
PLACE: Jefferson Memorial Auditorium, USDA, South Building

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If you would like to have a copy of this announcement, please call the Graduate School, Ext. 6337, or come to Room 1031.

graduate school U. S. DEPARTMENT OF AGRICULTURE

The Significance of Progress in Chemistry to Agriculture

By Reid T. Milner, Head
Department of Technology
University of Illinois

It was a great pleasure and a compliment to me to be invited to present one of these lectures to the Graduate School of the U.S. Department of Agriculture. I have known and admired the Graduate School for over 25 years. At the old Fixed Nitrogen Laboratory some of my ablest colleagues were giving courses in the graduate school, and over the years I have been impressed by the high quality of the teaching staff. To join this illustrious group, even for one occasion, is an honor that I much appreciate.

The topic of this lecture is a difficult one to cover adequately. "Chemistry" and "Agriculture" are such big subjects, so much is already known in both, and progress is so rapid, that one speaker for a single occasion has many limitations. It is possible to discuss in some detail progress in the separate parts of chemistry such as inorganic, organic, physical, analytical, and biochemical. Similarly, the advances made in soil research, fertilizers, plant chemistry, plant physiology, entomology and allied fields have been closely related to chemistry and are a part of my subject. What I shall give you, I fear, is a mixture arranged to fit the time available and my own concept of the subject. The thesis that I hope to develop and the thought that I wish to leave with you is that while great progress has been made in both agriculture and chemistry, the future looks even more promising. Furthermore, the rather spectacular advances in the application of chemistry seem to me to indicate the pathway which will lead to the greatest progress in agriculture.

Agriculture means food. For thousands of years, the main problem in every country has been to produce enough food so that starvation would not be a continual threat. In this country through most of our history we have been fortunate in our agricultural efforts, and agricultural progress has given us a rising standard of nutrition and a diet which today is unrivalled for value and variety. Within the last five years, however, there have been many reports pointing out that if our population continues to increase at its present rate, progress in agriculture must accelerate to maintain our present standards in the future. Predictions on this subject have named 1975 as a time for serious concern. In contrast to the possible lack of sufficient high quality food 20 years from now, we are faced at present with what appears to be a super abundance of food for the immediate future. These conditions, of course, apply only to this country. Now as in the past, there is not enough food for all the people of the world.

Our present problems in agriculture are difficult and pressing. Because we face them each day, they are hard to see in perspective. Over supplies of a few commodities, dislocations of supply, demand and distribution, and factors outside of agriculture both domestic and foreign all play a part in our present problems. It seems to me, however, that cheaper production with fewer losses, better preservation and conservation, improved distribution and more knowledge of marketing can all contribute to agricultural progress and help solve our present problems. These measures are in turn aspects of greater efficiency in agriculture.

Lecture at the Graduate School of the USDA, Washington, D.C., January 19, 1955.

Also, as our population grows, and as we live longer, many of our foods abundant now must be produced in even greater amounts. Food adequate for the 200,000,000 predicted for 1975 is not being produced now. It seems obvious that a great deal of effort and study will be required for progress on both our present and future problems. Research and study take time. Experience also shows that time is needed to translate research results into practical applications. In undertaking research to help agriculture we must consider both the present and the future and look for assistance from all possible sources. A survey of the changes and progress in chemistry with emphasis on their agricultural applications may be of aid to agricultural research.

This has been referred to as the "Chemical Age". Certainly anyone whose attention has been focused on one of our typical important American institutions, the stock market, could support this belief. The American investor by his strong support has helped create dozens of big, diversified chemical industries. Apparently confidence in the future of many of these companies remains strong, because their stocks are popular with investors although they sell at prices which return very low income. Purchasers of these stocks are looking to expansion in the future and a continuing chemical golden age.

Let us assume that the American Chemical industry started in World War I. Certainly there were chemists in schools and in companies before then, but it was in this period that as a Nation we began to appreciate the importance of chemistry. Lack of dyes and chemical warfare were excellent publicizers for this science. Since those years American chemistry both scholarly and industrial has assumed a leading role in the world. Six Nobel prizes and an industry unequalled in value or output testify to the present strength of American chemistry. What is responsible for this extremely successful development? Some of the factors that led to the remarkable advances in American chemistry may help agriculture to progress toward answering the problems we face.

It is a little disconcerting to realize that in this period since 1914-18 there have been relatively few great advances in theory or basic principles. The advance in nuclear chemistry is one of these. This field is so new that we still do not know the magnitude of the discoveries now being made. The lecture you will hear on "The Significance of Progress in Atomic Energy to Agriculture" will go into this subject however. Another great advance was the formulation of the principles of polymer formation by W. H. Carothers in the early 1930s. We will return later to this important work. Other advances of theory have been in biochemistry especially in the field of hormones and sterols. The concept and discovery of antibiotics can also be listed as a major advance of the past 40 years. With the exception of nuclear chemistry none of these seems to have the possibilities for clarifying and advancing the progress of chemistry that were afforded by the work of Willard Gibbs, Nernst or Arrhenious in laying the foundation of thermodynamics and solution chemistry in the last half of the 19th century.

I should like to emphasize the role that chemical analysis has played in the progress, growth and development of chemistry since the teens. In the period 1915-20 there was relatively little interest in analytical theory, methods, or tools. The great usefulness of the quantitative microanalytical methods developed by Fritz Pregl was an eye opener to the chemical world. It is no exaggeration to say that the development of microanalysis made possible many of the advances in organic and almost all in biochemistry. It is difficult now, when a few milligrams of material suffice for a quantitative elementary or group analysis, to recall the days when several grams of material were needed. In isolating an

unknown vitamin or hormone or in attempting to purify a new antibiotic, it may be necessary to process tons of material or to carry out a long series of reactions extending over many months in order to obtain several hundred milligrams of material. There are many instances where less than one gram of such a product, thanks to microanalysis, has been enough to furnish a proof of structure, properties of some derivatives, animal tests, and a few clinical trials.

Physical instruments also made possible great advances in analysis. With the discovery of glass electrodes and the ready market for the convenient vacuum-tube, glass-electrode pH meters, instrument makers began a strenuous effort to assist the analyst in physical tests. Simple electronic filter photometers were developed for measuring color. These were followed by abridged spectrophotometers using grating replicas. Finally a true laboratory model quartz prism spectrophotometer appeared which used a narrow spectral beam and permitted light absorption measurements from 2200 Å in the ultraviolet through the entire visible range and into the near infra red. This instrument was easy and convenient to operate. It was quick and gave results directly from a meter instead of requiring exposure and development of plate or film. Finally it was much cheaper than the earlier elaborate spectrophotometers. It opened entirely new fields to analysts and made possible a knowledge of the structure of fatty acids as well as many other natural products. The ability to identify and determine the various isomers of the unsaturated fatty acids has made possible a great expansion in their use for both food products and industrial purposes.

Other more complicated and expensive instruments soon appeared to help the chemist. Infra red spectrophotometers are now available with almost the same ease of operation as those used in the ultraviolet. X-ray apparatus for "finger-printing" chemical compounds by their diffraction patterns, and mass spectrographs for sorting and measuring the molecular weights of complicated ion mixtures are now in almost all large research laboratories. Electrophoresis and ultracentrifuge apparatus, while less generally available, can be purchased complete and ready to operate. Twenty years ago such equipment was constructed and used in only a few laboratories. Finally one of the most remarkable techniques developed to aid the analyst requires no expensive apparatus at all. Tswett developed his absorbent columns of chalk for use on chlorophyll separation. Now numerous solids are used in chromatography, with many variations of procedure. Paper chromatography because it is cheap and simple has permitted separations never believed possible. Chromatography has proved especially valuable in distinguishing and separating the numerous pigments found in nature.

With microanalysis, these new physical tools, and increased respect from other scientists, analysts have developed new methods of product control. These methods make possible the fractionation and separation of pure materials from complicated mixtures. Automatic and strict control of process streams plays a deciding role in the production both of metal alloys and synthetic hormones. Analytical control in a very real sense makes possible the application of chemistry to manufacturing.

The analyst's role in the progress of chemistry has been important, as I have tried to show. The role of the chemical engineer has been equally important. The principles behind the analytical instruments for the most part had been discovered in the late 19th century or before 1910. Likewise almost all of the chemicals now produced and sold in large tonnage had been made and were reported

in Beilstein. In general no new theories were required to make them, but the design of economical and efficient apparatus and processes was essential. Chemistry had a background of data and theory. When the demand for chemicals came, the factories soon grew and the products appeared through the efforts of chemical engineers.

Remarkable progress also has been made in American agricultural production in this century, especially since 1935. Increased use of new and improved farm machinery has led to much greater farm output per man hour. Crop production per unit of area has risen. These are convenient and significant measures of increased efficiency but they do not show the details or means by which these increases were achieved.

Greater knowledge of soil structure, chemistry and microbiology has contributed to this progress. Enthusiasts have argued the merits of "organic" vs. "commercial" fertilizers with considerable warmth. There is much evidence to show that the combination of organic farming with chemical fertilizers is the best answer we know now for high production and soil conservation at the same time. X-ray studies have led to an understanding of clay mineral structure and to the way these structures function in the soil. The function of organic matter in the soil is becoming known. The recent announcement of soil conditioners has created a great deal of interest and started much additional research in soil structure. At present, however, it seems that the proper rotation of crops with commercial fertilizer used in the most efficient manner possible represents best practice. Much more needs to be learned. Can selected types of organic material added to the soil have an antibiotic effect? Some evidence exists for this view and the "organic" farmers have claimed freedom from disease and insects for their products. The discovery of the importance of trace elements especially in certain types of soils has subtracted a great deal from the prestige of "organic fertilizers". A. F. Camp of the Florida Citrus Experiment Station has stated, "a properly balanced program supplying all the needed elements, either in fertilizer or sprays, would surpass in all probability the best organic mixtures that were ever available in Florida - or, I believe, anywhere else".

Starting in about 1935, in addition to the nitrogen, phosphorus, potash, incidental calcium, and sulfur of fertilizers, other elements were added until now the program includes zinc, copper, manganese, magnesium, boron, and molybdenum as well as an available form of iron. The results of this research on trace elements have been spectacular in the citrus industry. Not only yield but quality has been improved. The necessity of trace elements has been established very clearly, but their amounts must be regulated according to the crops grown. The complete fertility program should provide to the crop in available form all the elements needed for maximum quality and yield. If these elements are not available in the soil, they must be furnished in proper form.

The recent development of the agricultural chemicals industry has been one major forward step in agriculture. The industry is now a large one. For the past five years, the production value of basic pesticidal chemicals alone has averaged over 150 million dollars. The losses of crops which farmers face are tremendous. The Department of Agriculture's estimate of 13 billion dollars' loss due to insects, diseases, parasites, weeds, inadequate harvesting, mechanical damage, weather and similar hazards is probably very conservative. Agricultural chemicals used for insecticides, herbicides, and fungicides offer a chance to greatly reduce this huge loss.

In the early years of this century until the forties, farmers had available for fighting insects only the inorganic poisons such as copper, lead and arsenic. When DDT became available and scored a spectacular success some felt that the day of the inorganics had passed. Experience has shown, however, that in general a new insecticide does not extensively replace the others but rather extends the weapons farmers have for preserving their crops. The introduction and use of DDT, BHC, rotenone, pyrethrum, parathion, TEPP, Chloro IPC, toxaphene, aldrin, malathion, and dieldrin have provided economical controls for many specific pests. Many of these compounds had been known as chemical curiosities. Their specific effects against destructive insects have been the new discoveries leading to their large scale production and use. Systemic insecticides seem to offer the most revolutionary development for the next few years. These are receiving a great deal of study designed to increase their activity against chewing insects and to reduce the hazards of their use.

Organic herbicides as we now use them have a history of only about 10 years. Compounds of the phenoxy dinitro and carbamate type comprise most of these chemicals. Much information on their specific action and best method of application is still lacking. Enough has been learned and sufficient applications have been made, however, to show that selective herbicides offer great promise to agriculture. These chemical agents are the only effective means now available for controlling weeds in some crops such as wheat, oats, barley, rice and flax. Their use for cereals and cotton promises considerable economy. Finally, chemical herbicides offer a means for controlling weeds in pastures, and sage brush and mesquite on range lands. Progress by chemists in the preparation of numerous analogs and homologs of those chemicals useful as insecticides and herbicides will continue to offer agriculture an opportunity to greatly reduce the losses due to insects and weeds.

The use of antibiotics in animal feeds, started about 1950, has contributed substantially to the rapid growth of the poultry industry. The gains in feed economy and improved health with swine and poultry were made possible by the cheap production of antibiotics. The wide range antibiotics, penicillin, oxytetracycline, and chlorotetracycline have proved most effective. These, combined with the newly discovered vitamin B_{12}, have provided new and improved feed concentrates for non-ruminant animals. The economical production of these better feeds was made possible by the large scale, cheap production of both B_{12} and antibiotics as a result of excellent chemical engineering work on both production and recovery. In fact, antibiotics are now being produced so cheaply that their use for prevention of plant diseases is receiving serious study. Streptomycine is apparently the most effective remedy so far discovered for fire blight of fruit trees. The research and field trials are still proceeding, but it appears possible that a new and important field for antibiotic use is opening in this area.

All of these areas of progress in agriculture, dependent on progress in chemistry, have related to more efficient production or protection of crops. Equally significant advances in the more efficient use, preservation, and marketing of foods have resulted from chemical achievements.

The general theory of polymer formation developed by Carothers resulted directly in the production of the synthetic fiber nylon. The same principles, however, were immediately applied in many other directions. The newer packaging materials now widely used in retail markets include polyethylene, pliofilm and saran. These are synthetic polymers, created from petroleum derivatives, and have qualities of moisture-vapor permeability, toughness, flexibility, plasticity, and transparency never before available. Use of these films has lengthened the storage and shelf life of a multitude of agricultural products and greatly reduced

losses, especially of fresh produce. The trend toward even greater application of these flexible films seems clear and can be effected to bring about more efficient marketing of foods.

A very striking example of the impact of chemistry on an agricultural product has been the growth of the citrus concentrate industry. After the collapse of the great boom in Florida real estate in the twenties, a slow steady growth in population of the State took place. A large number of small citrus groves were planted. Citrus production expanded steadily with more and more young trees set out. In 1944 the production of citrus seemed to be headed for hopeless over expansion. A large acreage had been planted to trees which would begin to bear shortly. At the same time the available markets for fresh fruit were apparently approaching saturation. It was at this point that chemists of the Florida Citrus Commission and of the U.S. Department of Agriculture jointly worked out the method of preparing a flavorful orange juice concentrate. The high quality of this frozen concentrate and the low retail price brought immediate consumer acceptance. In 1945-46, 226 thousand gallons were produced while in 1953, 37 million boxes of oranges (46.5% of the crop) were used to make 61 million gallons of concentrate. Frozen concentrated orange juice has not only rescued the orange growers from fear of overproduction but also made possible a considerable increase in vitamin C in the American diet.

One of the most striking developments in agriculture in this century has been the rise in soybean production and use. Without detracting in any way from the great accomplishments of the plant breeders, the chemists have also played a major role in the success of this new crop. Small quantities of soybean oil and oil meal were imported into America long before they were produced here. The oil was used largely for paints and the efforts to use it for edible purposes met with little success. Even when the U.S. Regional Soybean Industrial Products Laboratory was established in 1936, the Department was urged to direct its research toward better paint oils. However, as all of us know, over 80% of the soybean oil is now used for edible purposes. As shortening, margarine, and liquid salad oil, soybeans are furnishing the major portion of our domestic vegetable fats and oils. Formerly soybean oil was severely discriminated against. It was used only in the lowest quality products and then largely because it cost from 2 to 4 cents per lb. less than cottonseed oil. A determined attack by chemists in industrial and government laboratories has resulted in products from soybean oil which are almost indistinguishable from those made of other oils. Improved methods of refining, bleaching, and deodorizing were developed. Metal scavengers and new antioxidants were discovered. Perhaps the most convincing demonstration of the present favored status of soybean oil occurred last year. Several companies found that when cottonseed oil was cheaper and they wanted to use it, they were unable to produce cottonseed products equal in quality to their soybean fats and oils. At present the price differential between our two major domestic vegetable oils is very slight and is largely dependent on the relative abundance of the two oils.

This triumph of chemistry has been exceedingly valuable to the national economy as a whole. Soybean oil meal has comprised a major portion of the available protein concentrates. Its development for this use would have been impossible without an accompanying use for the oil. This past year it is estimated that 343 million bushels of soybeans were produced. This American record crop will yield 6.5 million tons of oil meal and 2,870 million pounds of oil. Chemical research has provided the methods of alkali refining, bleaching, deodorizing, and hydrogenating which transform crude soybean oil into shortening and margarine

stock. To a great extent it has replaced the imports of palm and coconut oils. Without the successful development of soybean oil for edible purposes, the fat shortages in this country especially during the war years would have been extremely serious.

The examples of progress in chemistry so far discussed and the applications of chemistry to agriculture are clearly beneficial to agriculture. Some notable chemical progress, however, could be regarded as reducing greatly the use of agricultural products. Three examples come to mind at once. Polymer chemistry has led not only to films but also to synthetic fibers. Among the products of synthetic petroleum chemistry, two of the simplest are ethyl alcohol and glycerol. When Nylon, Dynel, Dacron, Acrilan, Orlon and the other synthetic fibers first appeared on the market, there was some fear that the markets for wool and cotton would suffer severely. Instead, the situation seems to be similar to that of insecticides, where a new chemical finds certain uses in which it excels but does not supplant the older and cheaper materials. Also, textile manufacturers are now finding that blends of synthetic and natural fibers can combine the best properties of both. Research on cotton fiber for example has moved into new fields where polymer chemistry is used to modify cotton to an essentially new material. Since synthetics have demonstrated some of the desirable properties that fibers can possess, research on cotton and wool promises to confer these properties on the natural products in addition to their present desirable traits. Some desirable characteristics first known in synthetics can now, thanks to research, be added to natural fibers in addition to their own desirable properties.

Synthetic enthanol made from petroleum has very largely displaced fermentation alcohol from grain except for beverage purposes. However, in this field also the competition from the cheaper source has stimulated research and resulted in improvements in the efficiency of the fermentation process. Low cost, by-product molasses still is competing with petroleum, and by-product or waste carbohydrates will always act as a stabilizer on the price of ethyl alcohol.

In the case of glycerol, competition from synthesis has displaced some of the natural product. Glycerol was formerly obtained almost entirely from fats and oils as a by-product of soap making. When synthetic detergents cut into the market for soap, glycerol production was reduced. This deficit in supply will be remedied by the synthetic product. In this case, however, there is some doubt about the eventual economy of synthetic as compared with natural glycerol. If fatty acids from fats and oils continue to find increased uses and outlets, the glycerol resulting as a by-product should be able to compete with glycerol made from propylene.

Looking far ahead, we may speculate that with sufficient increase of population, land may become too scarce to be used for any other purpose than food production. If this comes to pass, then the availability of synthetic alcohols and fibers will be essential. There is, however, the possibility that by that time the price of products from petroleum, oil shale, or coal may be so high that agricultural residues such as wood wastes or crop residues will become important. Enough research has been done to show the possibility of using these materials either to produce cellulose or carbohydrate derivatives. It is impossible to predict the economics, markets and supply and demand of the future, but it is certainly desirable to know how to make any given product from as many sources as possible. Progress in chemistry may develop products competitive with agriculture at the same time that it assists agriculture, but the overall effect is gain for farmers as farmers and as consumers. If our research efforts

had been limited to the improvement of soybeans as a forage crop, for example, when war came in 1941 fats for our table, paint for houses and tanks, and soybean protein for fighting fires on Navy ships would not have been available.

What is the path for future progress in agriculture? As it relates to chemistry, it seems that continued and further efforts along the lines that have been followed will be successful. New tools and new techniques are being developed in many fields. These should be applied to agricultural problems. I have seen many pictures of a mass spectrograph or an infra-red spectrophotometer installed in the product lines of petrochemical plants. I do not recall seeing these instruments used on an agricultural product line such as a cow's rumen or respiratory tract. If these complicated machines can measure almost instantaneously the kind and amount of materials circulating in a pipe line, could they be adapted to the sap stream of a tree or a plant? With radioactive fertilizers and an increasing number of radio tracer compounds becoming available we are able to learn more about the mechanisms of living plants and animals. Such studies will require not only expensive and complicated instruments but also the combined efforts of teams and groups of specialists from many different fields. Agricultural chemistry or chemical agriculture needs the services of agronomists and analysts, of entomologists and engineers, of bacteriologists and biochemists, and of pathologists and physicists.

There is need for more than team work and the application of known techniques and instruments. As more is discovered about living plants and animals, their chemistry appears increasingly complex. Enzyme interactions and mechanisms present a complicated picture. These reactions are involved in resistance to diseases and insects, growth, inheritance, and all the aspects that we try to control in improving agriculture. Along with progress in applying chemistry to agriculture we must also look for basic principles underlying the biological phenomena observed. Accumulation of data has been the necessary, but not sufficient, condition for theoretical advance. I know of no better way to progress than to encourage research by good organization, good equipment and good leadership. Since I am no longer an employee, perhaps it is proper to add that I believe all three of these qualities are in the Department of Agriculture.

RTMilner
1/14/54

The Significance of Progress in the Social Sciences to Agriculture

By

Murray R. Benedict [1]

I shall not attempt in this brief summary to discuss progress in the whole broad field of social science. It seems to me more useful here to think of developments in the Department of Agriculture and the State colleges and universities than to wander too far afield. Joseph Schumpeter's recent book on the history of economic analysis alone runs to 1200 pages not to mention the discussions and controversies growing out of it. Jacob Viner refers to it as "an over-ambitious book" and comments that there runs through it "a vein of pretentiousness and of intellectual arrogance."

I must disclaim at once any feeling of intellectual arrogance. One cannot, as I have done in the past few years, examine the developments in the Department of Agriculture without being impressed by the great progress that has been made; in the improvement of basic data; in the development of analytical techniques and in the application of research findings to practical problems. My comment here refers principally to economic research. Progress in the natural science fields, I am sure, has been similarly impressive, but that is not the subject of our discussion here today. You have, of course, been hearing about it from people eminently well qualified to discuss it.

I do want to comment later on the problems and possibilities of more effective collaboration between the natural scientists and the social scientists since that, in my opinion, is one of the directions in which further progress can and should be made. In the main, the work carried on in the agricultural research institutions implies practical applications though there is, of course, a large and growing field for basic research. To the extent that the emphasis is on applied research, there is obvious need for integrating the contributions that can be made by both the natural scientists and the social scientists.

Before attempting to describe the developments in the social sciences, I would like to point out some of the differences in the problems faced by researchers in the social sciences and those that are characteristic of the natural science fields. However, it is easy to exaggerate these differences. Some years ago, we had at the University of California a continuing informal conference on the problems relating to conservation research and policy. Among the participants were soil scientists, foresters, chemists, historians, economists and various others. Most of us, I think, were more impressed with the similarities and interrelations of research interest than by the differences. However, there are differences that are important.

The social sciences are concerned primarily with people and their behavior in producing, selling and using economic goods and in their relations with each other. This introduces two factors that affect research techniques markedly. First, there are few types of social science research in which the effects of

1/ Lecture given at the Graduate School of the U. S. Department of Agriculture, Washington, on February 2, 1955.

other factors than the one under study can, to use a hackneyed expression, be held constant. The effort to measure and allow for influences exerted by factors other than the one of primary interest must, in most cases, be implemented by the use of statistical techniques rather than by controlled experiments. Secondly, since the social sciences deal with the behavior of people, the decision-making powers of the people themselves must be taken into account.

If a chemist combines two elements or compounds, he can predict with great certainty what the result will be; and it will be the same if he repeats the process a year or ten years later. A physicist can measure the speed of light and the light waves will not, on their own account, decide to move at some slower or faster rate or in some different direction. When the behavior of people is the subject of study, no such precision of result can be assumed, even though the surrounding conditions seem to be similar. Usually, even the factors conditioning the reaction will not be the same.

Few of the social sciences can be sharply segregated. People do not necessarily react logically. A customary economic relationship may be greatly distorted by psychological factors, changes in the level of economic literacy, government policies, or even by changes in technology which have resulted from progress in the natural sciences. For example, the increase in spendable income that occurs in wartime does not exert its normal influence on prices. People hold more of it in savings, perhaps with the result that its inflationary effect appears at a later time. Spending may be held down by price controls, rationing and patriotic appeals, or consumption may be stimulated by subsidies advertising and propaganda.

Habit and style changes may affect consumer attitudes and behavior significantly. For example, people have shifted away from wheat products and potatoes and toward meats, fruits and vegetables, not only for health reasons but because the slimmer silhouette has become popular. In the matter of economic literacy, it used to be fairly safe to predict a large increase in potato acreage after a year of high prices. The ups and downs in potato production and prices were striking and notorious and, to some extent, predictable. But farmers have become more aware of these tendencies and are now less likely to behave in the same way as they did in earlier periods when they were less aware of the factors affecting the prices of their products. Coupled with these decision-type changes are the well-known uncertainties resulting from weather, disease infestation, and so on

These peculiarities of social science research point up sharply one important difference that is often overlooked, though it affects profoundly the atmosphere in which the two types of investigation are carried out. In many types of natural science research, the investigator is fully warranted in spending years, or perhaps even a lifetime, in refining his results, increasing the precision of measurement, and so on. If he gets the right answer, he makes a contribution to the body of knowledge in his field that will stand perhaps for all time or at least for a very long period.

Seldom can the social scientist expect, except perhaps in the field of history that his results will have such lasting value. Consequently, the degree of precision he is warranted in striving for, already severely limited by the nature of his research materials, is further curtailed by the fact that the specific conditions to which his research relates are not likely to be reproduced or reproducible in later periods.

Only in very fundamental types of relationship involving large aggregations is he warranted in spending great amounts of time and effort in developing extremely high precision in the measurements he works with. He is likely to be more concerned with fairly close approximations that can be derived quickly and used promptly. Thus, there is a significant difference in the time element as between the social sciences and the natural sciences.

Though these differences are readily apparent, they can easily be exaggerated. Precise measurement is far from easy in the natural sciences, and in many of them very similar problems requiring highly refined statistical techniques are necessary. The science of statistics in fact has its roots in the biological sciences rather than in mathematics or the social sciences. Even in the natural sciences, control over some of the factors that affect results is often difficult or virtually impossible.

We need only to think of the problems faced in the effort to classify soils in terms of productivity, the measurement of results from the use of soil conserving practices, or the variations in assimilation of nutrients by different animals, to be aware of the difficulties of measurement that are inherent in natural science research as well as in the social sciences. Even in such a field as medicine, where the researcher may have the active and intelligent cooperation of the subject, and no problem of changes in motification and attitude, the determination of such a relationship as that between cigarette smoking and lung cancer is presenting difficult and as yet unsolved statistical problems.

As much as a century ago, Thomas Henry Huxley outlined what he regarded as the four basic elements of scientific method, namely, (1) observation of facts; (2) comparison and classification of facts leading to induction to general propositions; (3) deduction from general propositions to facts again, so as to foretell facts in advance of observations; and (4) verifications of deductions by fresh observations. Huxley was seeking then to justify including the study of biological sciences in the educational program. However, his propositions still are significant in both the natural sciences and the social sciences. The pace is faster in the social sciences and the value rating of precision as against timeliness is lower. Yet both must be based fundamentally upon the observation of facts, on statistical generalizations and, if they are to deserve respect, on verification through fresh observations.

I have emphasized thus briefly some of the differences and similarities in the social and natural science approaches, mainly because of my strong conviction that each has much to gain through closer contact with the other. Further than that, I am convinced that the time has come when we must increasingly seek to devise workable ways of using the resources of a number of disciplines in studying the complex problems we are faced with. That is not easy to accomplish as you well know. Individual research is much easier to organize and carry out than group research. In many fields, it has and should have an important continuing place. But group research is gaining in importance. The knowledge and skills required and attainable in respect to the many facets of such problems as conservation, farm policy and production adjustment cannot be encompassed by single individuals in the life span granted to us, even though that life span is longer than it used to be.

The alternative is teamwork on the part of specialists. Some but not all of them. I would be the last to disparage the importance of intensive, individual and highly specialized research on narrowly defined research projects.

Nevertheless, there are other fronts on which advances must be made as well. We have made considerable progress in the collaborative type of research, but I for one do not think we have yet developed satisfactory methods of organizing it and suitable techniques for carrying it out. Effective collaboration among researchers in a given discipline, though not easy or simple, is less difficult than the conduct of studies requiring skills drawn from a variety of disciplines. Yet the latter type of study is coming to be more and more necessary.

Let me illustrate briefly, first in the social science realm alone. Many studies, pronouncements and special pleadings are being put out in the field of farm policy. Mostly, these are coming from the economists. Yet, even the most superficial glance at these problems reveals the fact that the techniques of the political scientist are needed in illuminating various aspects of some of them, especially in evaluating the trends in political and social structure. The more subtle and probably more fundamental elements of these problems, those relating to value judgments, carry us over into the realm of philosophy. Often these are brushed aside all too easily and superficially. We speak of more freedom for the individual, nonmonetary factors in real income, stability versus "progress" and the changing mores of farm people, but how far have we dug into these concepts to see what they really are.

Some of the reactions of farmers, and, of course, of other groups as well, stem from psychological influences and may be quite illogical from an economic standpoint, yet very real in their effects on the success or failure, or even the adoption or rejection, of given farm programs. Full understanding of reactions of that kind is not likely to be achieved through the researches of economists alone. Here the psychologists and political scientists have a role to play, though probably not so much within the governmental agencies as in privately supported research organizations. Unfortunately, studies carried out by such "other-discipline" researchers all too often are so lacking in contact with other types of reality that they do not serve as adequately as they might to strengthen and deepen the understanding derived from the more familiar and directly applicable studies carried on by economists and political strategists.

There is a place likewise for the anthropologist and the sociologist. In recent years, there has been a good deal of interest and writing about the very heterogeneous group known as "low-income" farmers, but we do not really know very much about the aspirations, abilities, handicaps and satisfactions of that group. We assume all too easily that they want the different kind of life we think they logically should want and that they could and would readily make changes in status or location if they were given opportunity. We may demonstrate fairly easily that a shift, perhaps to an urban occupation, would increase economic returns to them and improve the allocation of national resources, but also we may ignore some intangible values that rank high with them. In this realm there is a fertile and relatively unworked field for types of study that are now almost untouched in the Department of Agriculture and not much developed in the colleges and universities.

Of similar importance are the barely scratched problems resulting from the rapidly changing structure of farm and community life. Commercial farming, social relationships and community institutions are being greatly modified. The implications and probable later results of these changes are not well understood, nor is there as yet an adequate body of information for constructive planning in this realm. Also, we have a large, unstabilized and poorly housed farm labor group. Its existence is an economic and historical accident. Few commend it as a satisfactory way of performing necessary functions. But mostly it is not a problem

the individual employer can solve, no matter how good his intentions. It is far easier to damn it than to undertake the laborious task of devising methods and types of adjustment that will help in improving a situation that is generally regarded as deplorable.

These are only a few of the interconnections among the social sciences themselves which call for a higher degree of integration and collaboration in research. Similar joint interests appear as between the social scientists and the natural scientists. They are so obvious that I hardly need mention them. Only a few brief illustrations will suffice.

The animal nutritionist is concerned with the physical effects of given kinds and amounts of nutrients. The economist thinks in terms of the costs of different combinations and of their relation to the price of the product. The physical effects of a given combination of feeds do not change importantly, but the relative prices of feeds do change. The intensity and kind of feeding that will yield optimum net returns varies not only as a result of shifts in the relative prices of cost factors but also from changes in the relation between costs and the price of the end product. With butter or fluid milk at a given price, the optimum rate of feeding of concentrates may be quite different than if butter and milk are 10 or 20 per cent lower or higher.

Much time and expense are warranted in determining the basic physical relationships. But beyond this, economic studies to determine how to use such findings in making entrepreneurial decisions are also needed. These economic studies may require that sliding scale models of one kind or another be worked out to serve as guides for decisions that may have to be made at frequent intervals. The working out of such basic analytical frameworks on the economic side may require as high a level of precision and scholarly competence as the underlying scientific determination of physical relationships, but its effective use will be in the form of rough approximations in which timeliness will outweigh precision. The natural scientist need not be so much concerned with the time element.

Similar problems arise in the application of fertilizers. Certainly, precise results are far from easy to arrive at even on the physical side of the problem. But, even granting full success in this realm, the problem of economic optima in fertilizer application remains to be solved. Some years ago a subcommittee of a group I was working with undertook to bring out a brief report on fertilizer policy. It was prepared, for the most part, by a very distinguished group of soil scientists. Undoubtedly, from a strictly soil science standpoint, it was admirable. But from the standpoint of economics, the errors and gaps in it were so serious as to be a matter of unanimous and grave concern to the economist members of the parent committee who were later faced with the problem of passing on its suitability for publication.

I need not labor the point further. The interconnections among all of the research fields relating to agriculture are so numerous and so obvious that few are unaware of them. They are evident in the problems of forestry, pest and disease control, agricultural engineering, irrigation and plant and animal science. In some fields, such as forestry, the current trend is toward the development of economic analyses within the area itself. Conceivably, other branches of the Department could move in the same direction. But that would tend to dilute the basic scientific work of the Department in ways that might be to its disadvantage.

Furthermore, there still would be large segments of the economic work that would not find an appropriate home in any other unit but would nevertheless have to be carried on. The skills of economic analysts are readily transferable from one field to another and are particularly well suited to the analysis of joint product relationships, which cannot well be dealt with through approach in terms of a single type of product. Even in forestry, where the case for specialized economic research is undoubtedly strongest, the problem of competing uses for land is of great importance and requires other approaches as well as that of forestry itself.

I have postponed, possibly too long, a return to the central topic assigned for this meeting. My only apology is that it seemed to me difficult, if not impossible, to describe even in a roughly meaningful way what we might call progress in the social science phase of agricultural research without discussing briefly its nature and its place in the over-all program. Even so, this brief summary will have to be almost wholly in qualitative terms. There are many government activities to which we cannot assign quantitative values or results. The best we can do is to describe them. Each individual will have to place his own estimate on the need for them and the value of the product. Costs can be roughly measured. Returns often are intangible and certainly unmeasurable.

It is hardly necessary to say that the major research and service contribution in the social sciences has been in economics, both in the Department of Agriculture and in the State institutions. That is natural, since economic problems bulk largest in the thinking of farmers and legislators, whether at the State or national level. Hence, they are the ones for which funds are most likely to be provided.

The economic studies and service work of the Department seem to me to fall roughly into three major categories:

1. The collection of basic data. Here the Department has, in my opinion, made its greatest contribution. Without this enormous body of raw material for analytical work, most of the agricultural economics research both in and outside the Department would have been impossible. The United States now has a growing body of basic data that is incomparably better than that of any other nation in the world. It includes not only estimates of crop production and utilization but vast aggregations of data on prices, incomes, costs, mortgage debt, foreign trade, food consumption, farm employment and so on. Much of it is a joint product of the Department of Agriculture and the Bureau of the Census. Other parts, especially the price and income series are derived directly from the Department's own field surveys and other sources. The quality of these data still leaves much to be desired, but there has been steady and rapid progress in bringing them to higher and higher levels of adequacy and completeness, especially from about 1920 on.

2. The Department has made a sizable contribution in the form of analytical studies. This phase of its work is less fully developed than its data gathering activities and perhaps always will be. The analytical work has, in my opinion, suffered a serious setback in the decision to break up the Bureau of Agricultural Economics. However, there are obvious and perhaps inevitable limitations to the amount of strictly analytical

work on broad social problems that can be carried on by a government agency. That limitation is not confined to the Department of Agriculture. It exists also in the Department of Labor, in the Department of Commerce, and no doubt in other agencies as well.

3. There has been a very large development of what is sometimes called "operating research," that is, quick assembling of information needed in making administrative decisions, and rather rough and hurried analyses pertaining to some immediate problem. The trend in the last year or two, and perhaps in most of the years since 1930, has been in that direction. Those who are familiar with that type of work are well aware of three of its characteristics. First, it is necessary, in a government so heavily involved in the management of agricultural affairs as ours now is. Second, refinements and precision must often be sacrificed in the interest of timeliness and, third, it is very heavily dependent on the adequacy and scope of the reservoir of data, knowledge and analytical work built up before the need for it arose.

It is here that the losses resulting from breakup of the Bureau of Agricultural Economics are likely to show up most clearly as time goes on. That agency was, potentially at least, the reservoir from which specialized knowledge, qualified personnel, and the results of longer-term, more carefully made analyses could be drawn. The Bureau of Agricultural Economics was not, of course, the only source of such continuing and more basic research. Other branches of the Department were also contributing to it in a significant way.

The rough classification given above does not include a fourth phase of the Department's work which, though important, is less easily recognized. That is the gradual process of increasing farmer understanding of economic relationships. It can be doubted if this has been as much a conscious part of the Department's program during the past two decades as it was in the 1920s. Nevertheless, it has been a growing influence. No one who has worked with farmers over the past thirty or forty years will question seriously the gains in understanding that have been achieved, though this gain was not wholly, perhaps not even principally, a result of specific Department of Agriculture efforts. Regardless of the source of their knowledge, farmers do approach their economic problems now with far more understanding than they did only a few decades ago.

I should like now, in a rough way, to try to relate the developments in the social science fields to the general framework outlined above. It seems to me our purpose here will not be best served by attempting a detailed historical review, but rather by emphasizing changes in emphasis and over-all gains.

Some two or three years ago, H. C. and Anne Dewees Taylor brought out their large volume on the development of agricultural economics, the principal field with which we are here concerned.1/ It provides a good deal of detail about the

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1/ H. C. and Anne Dewees Taylor, The Story of Agricultural Economics in the United States, 1840-1932, Iowa State College Press, Ames, Iowa, 1952.

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about the evolution of agricultural economics as a field of study, though perhaps

not in as orderly a way as we might wish. So far as the Bureau of Agricultural Economics is concerned, I could not hope to add much to the excellent articles by Lloyd S. Tenney and John D. Black which were published in the Proceedings Number of the Journal of Farm Economics for November 1947. They are readily available to you. 2/

2/ "The Bureau of Agricultural Economics--the Early Years" and "The Bureau of Agricultural Economics--the Years in Between" Journal of Farm Economics, Proceedings Number, November 1947, pp. 1017-42.

In the broad field of scientific progress, the social sciences are recent, if we think of them as sciences rather than as systems of moral philosophy. No doubt some of you, as well as many others, have doubts that they have yet achieved a status that entitles them to be classed as sciences. Yet, their roots go back at least as far as the time of Aristotle and Plato, and the fumbling efforts to describe and understand economic relationships in the centuries between then and 1750 were perhaps not much more clouded by mysticism and metaphysics than those of the disciplines we now call natural sciences.

Nevertheless, hardheaded, careful efforts to observe, classify, measure, generalize and synthesize did develop earlier in the natural sciences, especially in the research program of the Department of Agriculture. Progress in these fields has been more solid and measurable but perhaps not more important in its effects on society. Until about 1900, there was not much attempt or opportunity to apply genuinely scientific procedures to the social science problems of agriculture. Up to that time, the funds provided were almost wholly in the natural science fields and it was there that professionally trained researchers first became available. However, some groundwork was being laid. Basic agricultural data began to be assembled as early as 1840 both in the Patent Office and in census operations. As early as the 1860s more carefully assembled data on crop production began to take shape and the recurring census enumerations, particularly from 1880 on, began to provide materials that were later to be of great importance to social scientists.

Social science problems and relationships were already becoming prominent in the thinking of farmers and their organizations in the late nineteenth century. But they were not looking to the Department of Agriculture, or to social scientists outside the Department, for help in solving them. The Department and the social scientists had little to offer, even if they had been consulted.

The years 1900 to 1920 were the formative period for the work in agricultural economics. But at that time, interest centered mainly on the economics of the farm unit, rather than on the larger national and group problems that came into prominence later. There was a reason for that. The concern over prices and the general economic organization of society receded into the background during the first decade of this century. Farm prices were rising rapidly. The farmer who could produce more efficiently on his own individual farm had a fair chance of success even if no momentous changes were made in the institutional setting or in national policies. Farmers were, to be sure, much interested in Teddy Roosevelt's trust-busting campaign and in food and drug laws, meat inspection, and so on, but on humanitarian and philosophical grounds, not because these measures were likely to increase farm incomes significantly.

This emphasis on study of the farm unit was approached in various ways. Hays, Warren, Boss and others were coming at it by way of Agronomy. They were familiar with the techniques then available in the agronomic sciences but not with those of economics. Consequently, they improvised as they went along, devising the cost-of-production route technique, the farm management survey method and some rudimentary approaches to the combination of enterprises. At about the same time, W. J. Spillman, whose background was in mathematics, began work on much the same type of problem.

H. C. Taylor and T. N. Carver were beginning to study and teach agricultural economics using as a background their training in economics, emphasizing the principle of diminishing returns, Ricardian rent theories, and some of the ideas of Francis Walker in respect to profits. Carver also gave attention to the history of agricultural development and Richard T. Ely, at the University of Wisconsin, was exploring and teaching about the institutional and economic aspects of land tenure. However, most of these early studies, whether undertaken by agronomists, mathematicians or economists, tended nevertheless to emphasize the problems of the individual farm rather than aggregative relationships. The data and techniques for such larger-scale studies were not yet available, even if there had been an active interest in undertaking them. Only toward the end of the second decade, when war demand and inflation were disrupting customary price relationships, was there much active interest in problems of that kind. G. F. Warren began to present and popularize his famous price charts in the years just prior to the great price decline of 1920.

There had, of course, been a growing interest in the marketing of farm products. It had its origin outside the Department of Agriculture, and the principal study in that field prior to 1900, the Report of the U. S. Industrial Commission (1898), was a result of congressional action and was not carried out by the Department of Agriculture. However, some start on marketing studies had been made in the Department as early as 1894 or thereabouts, chiefly in the study of foreign markets for farm products. Some criticism of the paucity of economic research was also beginning to appear in the reports of the Secretary of Agriculture.

Not much real progress in marketing research was made until Houston became Secretary in 1913. Then for the first time, the man in charge of the Department was a well-trained economist. But even then, and for some time thereafter, the marketing research undertaken was largely descriptive rather than analytical, except for that pertaining to the establishment of grades and standards, which was at least as much technical as economic. However, the crop and livestock reporting activities were put on a much more adequate basis from about 1915 on. Research and changes in organization looking to the improvement of crop estimates were important in the period prior to 1930 but came to be overshadowed by the operating activities of the Division of Crop and Livestock Estimates in the 1930s and after. Only recently has there been a revival of study and consultation looking to basic changes in the methods of collecting and interpreting such data.

During this second decade of the 1900s, there was other important progress in the field of agricultural economics, but mainly at the preparatory level rather than in actual research output. H. C. Taylor, Richard T. Ely, and B. H. Hibbard were training and influencing a group of graduate students at the University of Wisconsin who were later to exert much influence on the quality and scope of agricultural economics work in the Department. But the time was not yet ripe for them to enter upon the kind of program that was shortly to result in

the great development of data collection and analysis that was to mark the 1920s.

Interest was shifting from the rather narrowly conceived fields of farm management and marketing to the whole range of economic relationships affecting agriculture. Gray and Baker were turning to land economics, Stine to historical and price research, Holmes to a new type of farm management analysis, and Galpin was making some start on a descriptive type of rural sociology. John D. Black was getting ready for the extensive and diverse training program he was later to carry on at Minnesota and Harvard. G. F. Warren, too, was shifting away from his earlier preoccupation with farm management and becoming interested in price relationships.

With the severe break in farm prices that came in 1920 and after, the climate in which the new field of agricultural economics was growing became almost ideal for rapid and significant progress. H. C. Wallace, who was much interested in the economic problems of agriculture, became Secretary of the Department. H. C. Taylor, a primary leader in the field, was brought in to pull together and lead the various phases of economic research then underway, and to initiate new ones. The Congress was acutely aware of the price, income, credit, and marketing problems facing agriculture, and farmers and farm organizations were avidly seeking economic data and analytical material. Even the state legislatures were evincing an interest in the research side of the problem which had not characterized their attitudes in earlier years.

Taylor, as the first Chief of the Bureau of Agricultural Economics, proved a wise and able leader. He developed a strong team of enthusiastic and relatively well-trained division chiefs and others, many of them already exposed as students to his way of thinking. These were soon supplemented by others coming out of Black's group at Minnesota, Warren's at Cornell, and from various other places. In-service, graduate training was provided and some new fields were opened up. Galpin came in to head up a new unit dealing with the problems of rural sociology and rural life. New work was undertaken in the fields of credit, taxation, factors affecting prices and the organization and functioning of marketing organizations.

Even though Taylor himself was soon forced out as head of the Bureau of Agricultural Economics, the impetus given in the early 1920s, partly substantive and partly organizational, continued to carry the work forward at least until 1933. The drive for more and more activity in the study of economic relationships was, of course, intensified by the continuing unsatisfactory price, income and credit situation and the vigorous political struggle over the McNary-Haugen Plan. As the depression of the 1930s put agriculture in an even more desperate situation, economic studies were given still further emphasis, especially after the failure of the Farm Board gave rise to a search for alternative methods of attack on the farm problem.

What then can we say in a meaningful way about the nature and extent of the progress made between 1920 and 1933? While I regard that period as the one in which we have made our most important and fundamental progress from a technical and scientific standpoint, I cannot pinpoint it sharply. In rough, broad categories, I would indicate the gains somewhat as follows:

1. Agricultural economics had come to be recognized as a field in which first rate professional training had a place. Observation, generalization, testing of results and other scientific procedures were being developed though not in the same way nor to the same level of accuracy as in the natural sciences.

2. The collection and processing of basic data had been brought to a more adequate level and the initial impetus for continuing improvement in their scope and quality had been provided.

3. Research attitudes, training, and esprit de corps had been markedly improved.

4. Research horizons had been widened and many new kinds of problems were being brought under study.

5. Statistics, one of the basic scientific tools of the social sciences, was being more and more emphasized and techniques were being refined. More emphasis was also being put on adequate training in the principles of economics and their use in agricultural economics research.

6. A good deal of progress had been made in the identification and measurement of the factors affecting farm prices. In conjunction with this, the agricultural outlook program had been launched. Whatever its limitations from the standpoint of accuracy and reliability, that activity has long been recognized as one of the most effective devices for increasing farmer understanding of economic relationships.

7. New and more analytical approaches to the study of agricultural marketing had been initiated. For example, studies of the relationship between size of marketing unit and the cost of handling. A start had also been made in the study of land problems and policies. In the field of farm management, the budgeting approach had been developed and some start had been made in the study of type-of-farming areas.

Broadly speaking, the over-all achievement was that an important research institution had been built up, one that had already gained the respect of other statistical and research agencies in and out of the government. In the social sciences other than economics, not too much had been accomplished, except in the development of historical price series and similar semiservice lines, except for the important contribution of L. C. Gray in his History of Agriculture in the Southern United States to 1860. Sociological studies had not progressed very far and little, if any, work was apparent in such fields as political science, philosophy, and so on. Most of these, for reasons already mentioned, are not well suited for study in a government agency. Though their subject matter has a bearing on many agricultural problems, it gives rise to so much controversy and criticism that sizable appropriations for carrying on work of that kind are not likely to be made.

Development of Social Science Work from 1933 on

What may be termed a third period in the evolution of social science research and service in the Department began in 1933 and has lasted in one form or another until now. So far as we can now see, it seems likely to be continued for some time to come. The demand for economic data and analytical material increased enormously. The work already done in the Bureau of Agricultural Economics and related agencies proved a tremendous asset to the administrators of the new agencies then being set up. It can almost be said that, without that great reservoir of information, the programs undertaken in the 1930s could not have been launched or carried out.

But the new program was not an unmixed blessing for the Bureau of Agricultural Economics as a research agency. Progress was made, but mainly not in the Bureau itself, and mostly not in basic studies of lasting significance. The progress was mainly in recognizing new problems and opening up new fields of inquiry. Much of the research was on immediate and pressing problems and a good deal of it was of the operational, day-to-day type which might or might not be pushed to the stage of general distribution. The earlier work provided both a reservoir of information and a considerable number of trained and experienced people who knew how to gather and analyze data.

I do not make this comment in disparagement of the kind of shift that occurred at that time. There are times when the emphasis should be on the task of laying foundations, andthere are other times when part of the crew may well be called away for fire-fighting or rescue operations. The need for such emergency types of activity was declining in the late 1930s, but a further change in emphasis made in 1938 created a new type of confusion so far as the basic work of the Bureau of Agricultural Economics was concerned. This was the assignment to it of a policy-planning function in the fall of 1938. This, as Black points out, 3/ was to some extent a resumption, in a more formal way, of a relationship between the Bureau and the Secretary's office that had existed informally during the regime of H. C. Taylor.

3/ The Bureau of Agricultural Economics—The Years in Between," *op. cit.*, pp. 1033-37.

I agree fully with Black's basic conclusion that ". . . the Department of Agriculture needs a strong general staff, but . . . the Bureau should not be that general staff." Certainly the kinds of data and analyses that can come out of a research organization such as the Bureau of Agricultural Economics was intended to be are of utmost importance in policy making, but if the research agency itself must formulate and recommend policy, the objectivity and quality of its research are bound to suffer. Furthermore, the assignment of such a function to a research agency inevitably makes it subject to political pressures that not only detract from the quality of its work but may even jeopardize its continuing existence. Studies in the social sciences, relating as they do to matters on which legislators and farmers have strong emotional attitudes, are at best more vulnerable than those in most natural science research fields. This argues for special efforts to insulate the basic research from the intense pressures that center about the Secretary's office in carrying out its policy-making functions.

The amount of time available here does not permit of going into the additional assignment made at that time, namely, that of providing leadership in the county land-use planning program. Here also, the program contemplated had merit, but it is questionable whether the Bureau of Agricultural Economics was the agency best suited for carrying it out.

I have been tracing, in the main, the developments in agricultural economics and the closely related field of political science. Though the latter field has not been specifically recognized in the research program, many of the studies and actions undertaken had close ties with political science and, by implication at least, reflected political philosophies that were popular in farm and congressional circles.

I am not prepared to say that formal studies in the field of political science can and should be undertaken in such an agency as the Bureau of Agricultural Economics. I do think, however, that there is need for clearer recognition of the political science aspects of many of the problems dealt with, and for a somewhat more conscious effort to stimulate such studies in nongovernmental agencies, as well as to use the contributions that can be made by them. There is perhaps a need even for some continuing internal study along those lines but in ways that will not bring them too much into the limelight. Agricultural administrators make many decisions that imply the acceptance of political science principles and criteria, but seldom with implicit recognition of what they are. This vagueness may and undoubtedly does at times lead to inconsistencies and inadequacies. Such applications of political science principles are much like those of the laymen in using economic principles, without recognizing that he is doing so or being aware of the contributions that more formal economic analyses could make to the solution of his problems. A department so heavily involved in the management of far-reaching public programs as those with which the Department of Agriculture is concerned needs the kinds of information and guidance that trained political scientists can provide.

I should like now to turn aside briefly from this more general summary to mention some modest attempts to venture into other social science fields, mostly in a temporary and experimental way. I have already referred to the effort to carry on some limited types of work in the field of rural sociology. That work, as carried along under Galpin and Carl C. Taylor has been on a modest scale and, in recent years, has centered rather heavily on the fields of population and farm labor. Some of the work carried on by O. E. Baker also was of sociological character though not formally tied in with that division.

In the late 1930s, M. L. Wilson undertook to stimulate interest in the cultural anthropology aspects of farm life and thereby to broaden and deepen the sociological approach to the problems of agriculture. This effort did not come to fruition in any important way. Wilson's leadership was lost to it when he became Director of Extension, and such impetus as remained was largely pinched off by the growing preoccupation with war.

Related to this was an educational rather than a research effort, the "schools of philosophy" program which Dr. Carl Teausch launched just prior to World War II. This was an attempt to encourage and stimulate thinking about the basic objectives of agricultural work and living. It was a rudimentary attempt to look beyond the purely materialistic features of the government farm programs and to consider values of other kinds than the ones measured in dollars and cents.

This program too was soon abandoned and had no important carry-over, though it touched on an almost unexplored field. The easy assumption that, if farmers could achieve and maintain parity of prices or income or some other material goal, all would be rosy, needs more than a little challenging as anyone who knew farmer attitudes back in the early 1900s is aware. Perhaps this is not an appropriate function for the Department of Agriculture, or even for the government, but nevertheless, these abortive ventures did constitute an attempt to draw on other social science disciplines. They have a place somewhere in agricultural research but possibly not in the federal agencies.

World War II brought a continuation of the emphasis on emergency and administrative types of economic analysis. That was logical and no doubt necessary. It did, of course, largely preclude a quick return to the pre-1933 types of research and service. A good deal of directly applicable analysis was carried

on in connection with the production goals program and the administration of price controls. Some work was done on forward planning for the postwar period, but the conditions generally assumed were so different from those that actually arose that these studies proved largely inapplicable and unrealistic. That, of course, is one of the major handicaps of such plans. Some advance planning is necessary but it probably belongs in the executive and policy-making units rather than in the research agencies. My own view is that the most important contribution the research agencies can make in this realm is to maintain a large and diverse reservoir of soundly conceived studies that can be drawn on quickly in shaping plans for meeting new situations as they arise. This includes, of course, keeping continuously available up-to-date and comprehensive collections of basic data.

The postwar years have seen a return to somewhat greater emphasis on fundamental research, particularly in the production field. However, the Department's social science research program still is heavily influenced by the demands on it which grew out of the depression decade and those of the war and postwar years. It had not yet settled down on a solid, long-term program of research activity when the reorganization of 1953 changed the setting for the conduct of research of that kind. Most of the older series of data were continued or expanded during the 1933 to 1953 period, and no doubt will be continued under the new organization. New series have been added and many of the old ones have been improved. New techniques in the handling of crop estimates are being explored.

A considerable body of research has also gone forward in other branches of the Department such as the Farm Credit Administration, Foreign Agricultural Relations, and so on. Organizational changes and war influences have changed the emphases and content of these activities from time to time. In general, they have seemed to fall more largely in the operating research category than in that of fundamental research, though there are undoubtedly some exceptions.

Let me turn very briefly to the recent reorganization. It would be presumptious, I am sure, for me to venture dogmatic opinions about that. Those of us who are not here in direct contact with the new organizations have only fragmentary information to go on, and the plan is too new for it to show clearly either its advantages or disadvantages. Several brief discussions of it were published in a recent issue of the Journal of Farm Economics (in the February 1954 issue). 4/ With respect to the comments there presented, my own view

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4/ "The Fragmentation of the BAE," by O. V. Wells, J. D. Black, et al and P. H. Appleby, H. C. Taylor, H. R. Tolley, R. J. Penn, and T. W. Schultz, Journal of Farm Economics, February 1954, pp. 1-21.

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follows most closely the brief statement by H. C. Taylor. It seems to me that, while there is merit in organizing some types of research around particular problems, there is a great danger, as Taylor puts it, "of letting fundamental research 'fall between'" and of running out of basic background material. This danger has also been emphasized repeatedly by scientists concerned with what they regard as the overemphasis on "applied research" in the natural sciences. Taylor also emphasizes the possibility that there will not be enough qualified scientific people to make up the problem teams.

These defects, if they prove to be defects, will not show up prominently for several years. In the meantime, there seems to me a very real prospect that there will be a gradual deterioration in the quality and comprehensiveness of social science research in the Department, partly from the difficulty of recruiting genuinely research-minded people, if for no other reason. I hold no brief for the view that there is some innate superiority of the scientifically minded student of basic relationships over the man who deals with current problems. However, it seems to me to be common knowledge that the genuine researcher does not find himself greatly attracted by routine operating types of research. Hence I would expect some tendency for those interested in fundamental research to seek opportunities elsewhere and for the basic research of the Department to suffer as a result.

There are, of course, gains as well as losses. I have emphasized earlier the need for collaboration by social scientists and natural scientists. This may be more easily facilitated under the new organization than the old, but I am doubtful. Such collaboration is largely a matter of zeal and initiative on the part of the researchers themselves. It is not, as a rule, brought about by formal organizational arrangements. Hence it depends heavily on the atmosphere existing within each group.

The maintenance of a scholarly, research atmosphere seems to me more likely under the old bureau setup than under the present more impersonal one. Research organizations can easily become so large that the vision and enthusiasm of even a great leader cannot infuse the group with a spirit of teamwork and creative effort. I think there has been a real loss in the abandonment of the old bureau names. Perhaps one can become loyal and attached to a "Service" or a "Branch," but that seems to me to put an unnecessarily severe strain on his egoistic impulses. Furthermore, the new terminology is confusing and difficult for people who deal with the Department from the outside.

The old bureaus, such as the BAE, had personalities of their own. Membership in them meant something in the way of personal pride and group loyalty. I fear that some of that spirit has been lost and I doubt that a "Service" or a "Branch" can reinstill it. The Department has moved some distance in the direction of the single-purpose, impersonal type of organization that is characteristic of the research units of large corporations. However, even in the big corporations, there is a growing recognition of the need for greatly increased emphasis on basic research which is not directly related to immediate problems. That is not to say, of course, that there is no need for an overhead, coordinating agency in the research program of the Department. Obviously there is, but such agencies should be in the background rather than in the public eye, and there should be recognition of the need for pride and satisfaction in the accomplishments of a distinctive and appropriately named unit to which one belongs. Scientists either in the natural or social fields are not noted for their lack of egotism.

The above comments are, of course, purely personal views. Perhaps the time will come when I shall feel warranted in changing them. I have not been close to the new developments, as you here in the Department have been. Much will depend on the vision and inspiration the various administrators can supply. Research is after all a matter of men and their motivations and abilities, not of organization.

I have said very little about social science research in the colleges of agriculture and elsewhere, and the time available does not permit of going into it. In many respects, it resembles that in the Department. It has gained status and recognition in nearly all of the great universities. Research staffs are not only much larger than they were thirty years ago but they are very much better trained.

A good deal of progress has been made in the development of research techniques, in professional standards and in the attitudes of farmers and the public in regard to the work. Similar gains have, of course, been achieved within the Department of Agriculture. Some of the same gaps are evident in the work of the State institutions as those which have been mentioned earlier in describing the work here in the Department.

There is, of course, much still to be done before this, one of the newest of the fields of inquiry, develops methods, standards and reliability that are fully on a par with those of the older disciplines. Some of the older members of the profession feel that there has perhaps been a tendency for some of the newer work to be overconcerned with minute detail, at the expense of the broader, institutional phases of the problem. This is not to deplore a necessary and desirable striving for greater accuracy and precision but rather a fear that excessive concern with the individual trees may lead to a failure to understand the forest as a whole.

We have probably tended to split rather widely as between the very loose and unscientific studies of farm policy and the almost microscopic detail with which some researchers deal. There is an in-between area that needs also to be kept under study. It is in this realm that most of the practical working decisions have to be made. Also, we need, I think, to reach out more vigorously into the realms of historical perspective, value judgments and political institutions, all of which have a bearing on our problems.

Nevertheless, when we look back to the status of the social science phases of agriculture as little as forty years ago, and when we survey the quality of the articles and books now coming out, as compared to those of two or three decades ago, I think we must conclude that genuine progress has been made and that the contribution of the social scientists has been impressive.

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THE MEANING TO AGRICULTURE OF ADVANCES IN PHYSICS*

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A noteworthy and continued advance in agriculture has been in the use of machinery. This can be expressed as you might wish--in dollars per farm, acres per man, in horsepower per man, or in number of persons supported by each farm worker. The horsepower per man on American farms has increased more than five-fold since 1900. This is the chief contribution of physics to agriculture and is, accordingly, to be considered here.

As far as physics is concerned, the basic question is not the detail of the machine but the principles upon which it is based and its energy source. So, energy sources will be considered no matter whether they are the food for a horse or a laborer, potential energy of water, fossil fuels such as coal and oil, the sun, and finally the atomic nucleus.

In addition to the two topics of machines and energy sources, attention will be devoted to some aspects of the use of water, to weather and climate, to the creation of instruments, to a few mathematical questions, and some conceptual matters.

While you are well informed about agriculture, you possibly have given physics only casual attention and perhaps it is first before you here for your serious consideration. To make the treatment worth your time I then am forced to deal, at first and at later intervals, with the nature and development of physics.

Physics started a long time ago for some of its principles were discovered by prehistoric man. These include such things as the principles of some weapons and the making of fire. The advance, while recently so great as to make our time one of the several Golden ages of man, has been continuous, not even being obliterated by the dark ages of Europe during which Arabic civilization developed with its nuturing of mathematics and advances in practise of irrigation.

Physics deals only with the laws of nature as they are expressed from the microcosm of the atomic nucleus to the outer reaches of space. In this sense, physics was once called natural philosophy. The understanding of these laws of nature has led to their use by man. Thus, and by this means only, have come about the internal combustion engines of tractors and the electric motors of farm pumps.

Physics is an esoteric subject. In physics, perhaps more than in any other sicence, the nature of basic concepts has to be examined. Engineering is the practical side of physics. In fact, electrical engineering has much the same relation to the mother subject as the plastic or drug industry has to chemistry.

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*An address at the Graduate School of the U. S. Dept. of Agriculture on Feb. 8, 1955 as one of a series of lectures on Progress in Science.

The advances in physics that have created much of American agriculture were chiefly made in the eighteenth and nineteenth centuries. This belongs to what is called classical physics in contradistinction to quantum and relativistic aspects of the subject that developed from beginnings near 1900. Classical physics had its origins in the ancient world at the time of the ascendency of Greece.

Archimedes in the third century B.C. gave to physics its present form. He sought the laws of nature and to this end left a device, two famous sayings, and a symbol, π. One of the sayings which illustrates much of the spirit of physics is "Eureka, Eureka," or, in English, "I have found it," upon observing the water in the tub to overflow when he got in. The other is "Give me a fulcrum on which to rest and I will move the earth."

Archimedes recognized that the laws of nature are to be developed mathematically and thus fused physics indistinguishably with part of the more abstract subject of mathematics. At the other extreme, he joined physics to engineering by giving the latter mathematical exactness and removing it from mere management. In his engineering achievements first arose the dichomoty that has plagued scientists since his time, that of creating devices for use in wars rather than to aid man in his peaceful pursuits. On the one hand, he invented, or rather improved, the spiral which under his name is still in wide and peaceful use in Indian and Chinese agriculture for the lifting of water. On the other hand, he devised for Hieron, the King of Syracuse, catapaults that terrified the attacking Romans and prolonged the fatal siege of Syracuse for three years. But the Romans prevailed in the siege and Archimedes was run through by a spear while drawing a geometrical figure in the sand.

It is not a passing fancy of mine to refer to Archimedes at the start of this discussion. A visiting head of a soils department in a Western university, who happens to be a physicist, commented to several of us a few days ago that physics is still a Greecian subject. He made the reference in the sense that it is practically impossible to get physicists seriously interested in agriculture.

The Archimedes spiral might as well serve as an introduction to the part that physics, that is, the true basic understanding of the nature of things, in the physical world plays in the use of water in agriculture. Take, for instance, the integrated use of the water flow in the Columbia River for industry and for agriculture. As far as agriculture is concerned, the basic question is to get water to land that otherwise would go unused. But this land is above the level of the river. Work then has to be done to lift part of the water. The devices that make this practical are the water turbines and the coupled generators that use the potential energy of part of the water to produce electrical current to run motors driving centrifugal pumps to increase the potential energy of another part of the water. The overall efficiency is probably near 50 percent for taking water from the Columbia Piver and delivering it to the canal running into the Grant Coulee. The most recent improvements are in centrifugal pumps which alone make possible the handling of such great volumes of water.

Pumps, together with their driving engines or motors, of course are the only factors that make possible overhead irrigation as it is starting to develop in the eastern United States. This supply of water in the eastern and southern States is one of the most compelling changes facing American agriculture. Not only is the effectiveness of pumps involved but also cheap power.

Growing of crops without irrigation generally involves risk of water supply. Under irrigation, crop production and water use can hardly be efficient unless close accounts are kept on the water. The basis for this accounting was established about 45 years ago by a physicist in the Department of Agriculture. He is Lyman Briggs, who was long the Director of the National Bureau of Standards. Briggs assessed the way in which soils hold water in capillaries against the action of gravity. Plants can draw upon this water supply down to a limiting point. At lower water supplies, the plants wilt, so the critical point is known as the wilting point. The parameters of plant growth with respect to water and the capacity of the soil to supply the water are thus defined without detailed reference to the complexity of soil and the immense variety of plants. This is the heart of the methods of physics.

Let me say something about weather, of rain and cold, the vagaries of which are one of the great risks of farming. I do not have to develop for you the importance of weather forecasting to farming. Nor do I have to do more than recall to you that marked progress has taken place in weather forecasting during the last thirty years. Part of this progress has been the multiplying of stations for observations and improvement of communication, the later of which was effected through advances in physics. But, the entire subject of meteorology has advanced from understanding of certain basic phenomena in the atmosphere.

The starting point for me goes back about thirty years, when as a graduate student I had a course in hydrodynamics under a professor by the name of Bjerknes. To the students the most striking thing about Professor Bjerknes, in addition to his Norwegian accent and his austere face, was the fact that he gave general solutions to differential equations that others solved by less elegant numerical methods. The purpose in mentioning him here is that he, with his son, gave the basis of much of modern weather forecasting -- cold front formation and air mass movement. This is part of the understanding that physics has brought to the behavior of the atmosphere. The problem is essentially to find the behavior of a gaseous envelope on a rotating sphere. The envelope contains water as a condensable gas with a high heat of vaporization. The envelope receives heat from the sun chiefly at low altitudes and loses heat to space by radiation from polyatomic molecules such as water. The result of understanding the meteorlogical processes permits more accurate forecasting and this understanding alone underlies the hope of forecasting for periods as great as one week or longer. Now the citrus farmer knows exactly when to light his burners and knows how stiff and how long a task is before him; the cranberry farmer knows exactly when to flood his fields.

This understanding of weather as a natural phenomenon which is nicely developed in the Year Book of Agriculture "Climate and Men" has raised the possibility of tampering with it. The possibility is still largely speculative. It cannot be said that rain making is on a sound footing, or that snow can be controlled, but at least these matters are open to experimental attack. The basis for the attack is knowing something about storms at fronts, about unstable air in thunder storms, and about the formation of water droplets in the air. One of the experimental approaches, with which I associate the name of Irving Langmuir, is to study the nucleation of raindrops. It is surprising how effective silver iodide is in accomplishing this, irrespective of how practical it might be. I understand, however, that orchardists in South Africa around Cape Good Hope have greatly reduced hail damage by shooting rockets containing silver iodide into clouds. Sodium chloride, in the form left by evaporation of sea spray is also effective for cloud nucleation.

In the Keanea valley on Maui Island of the Hawaiian group, which is in the trade wind belt, the clouds come to the crest of a ridge and then blow across without rain falling in the lee. Water spray introduced from the ground into the cloud has given an average of about 200 fold increase in return to the land. Salt spray is also used in Hawaii on an experimental scale. While this and the hail storms in South Africa are admittedly special situations a principal, nevertheless, is established.

In the realm of speculation, too, at the movement is what might be done in a practical way about removing salt from water. The free energy increase is relatively small so the conditions are favorable for ultimate success. Evaporation and condensation are possible and straightforward as now in use around the Arabian Gulf and in Midway, but it is difficult to recover and recycle the heat, and the present processes are hopelessly wasteful. There are intriguing approaches, too, that involve passage of water through membranes of successive positive and negative charge. The possibilities are sufficiently inviting to justify research on the part of the Department of the Interior. A pilot scale plant is in operation in Arizona.

You can see that even Mark Twain is a vanishing American, for something more can be done than to talk about the weather.

Let us now turn to the machine in farming. In 1940 the investment of the American farmer in machinery and motive power was about three billion dollars. Today it stands at about twenty billion dollars. To attempt to contemplate the subject gets me off into all sorts of things about which I know very little. There is the matter of the individual merits of the machines, about the value of some elements of design, and about the turnover of a unit of money between the farm and industry. In the sense of physics there is one way out when faced by such a broad problem. That is to consider the basic principles for all the rest might merely be a confusing detail or repetition of the same pattern. Don't think from this though that a physicist, by understanding the nature of sound, could make a solo appearance as a violinist.

The use of steam expansion for power initiated the growth of industry. Steam still is of widest use but the reciprocating engine has been replaced by the multistage turbine. Steam engines were used in agriculture and some of the massive tractors can still be found rusting away in western junk piles. But they were not adapted to small machines.

It was the perfection of the internal combustion engine that essentially made possible mechanization of agriculture. Small efficient engines are possible and there has been a steady reduction in weight of the machine per horsepower. The volta pile became the eventual battery that is a convenient and engineeringly essential part of these machines. The helicoidal gear and the clutch system were sound in principle for transmitting power. There is the electric light for night work and the hydraulic lift systems. Each is based upon advance in engineering with the application of older physical principles, as also is the pneumatic tire.

The horse has surely disappeared as motive power in the United States. As Dr. Shaw, the Agricultural Research Service Administrator, has so clearly pointed out, this displacement of the horse since 1920 has been one of the chief sources of land to divert to food production for the growing population. This is entirely reasonable in the United States and even at some future time when

fossil fuels are not so abundant, fuel if necessary could be produced on the farm more effectively for engines than for animals.

We should not distort the power problem in agriculture in the United States so as to consider that it is desirable for all countries. I have been told in the Netherlands that on quite a few farms a most effective power source would be from a double purpose ox. In Japan it reasonably can be held that man is still an effective source of power. It is a social question, not a question of physics, as to whether one man without machines cultivates an acre or two or one man with machines cultivates ten acres or more.

A striking use of power and machines in agriculture is in the production of sugar in Hawaii. The Hawaiian problem is to get cane grown and to the mill with the maximum possible yield and the minimum use of labor. This is perhaps not different from the situation elsewhere, in principal, but in Hawaii they know it and act resolutely to meet the requirement. The machines have become very large since efficiency of operation per man is in that direction. This is possible as a result of continued improvement in diesel and gasoline motors. But with increased size of machine, some weighing of the order of 30 tons, and having several hundred horsepower, has come the question of land deterioration by compaction due to excessive load per unit area on the land. So, elements of design must not only be to accomplish the primary function of the machine but also to reduce the load per unit area. Or else the modified and compressed soil must be improved.

A recent possibility of machine operation for the farm might be mentioned. This is to have a self-propelled machine running an auxiliary electrical generator as a source of power for motors attached to drag machinery such as hay balers. Models of these have been built. In them advantages are to be gained in weight reduction by use of something like 360 cycle, but standardization of other equipment now requires use of 60 cycle.

The dairy industry possibly can be said, with a reasonable degree of fairness, to depend as much on the mechanical milker as upon the cow. The mechanical milker depends upon the use of a slight vacuum and in imparting the calf lip action to the teat. It attacks the labor problem at a bottleneck.

I am perfectly aware that beyond the discovery of basic principles upon which farm machinery is based there is a tremendous amount of invention, much by the farmer himself, or the successfulling putting together of known principles. There is also an effectiveness in the industrial production of the machine. To me a corn or cotton picker, a grain combine, or a hay baler is a wonder to behold.

In the realm of the farm machine ultimately the question comes as to why the particular operation is undertaken. If this is for cultivation, then the purposes of cultivation and the degree to which they are attained must be questioned. We only now are at the point of a rational examination. This, in part, has to do with the physical state of the soil.

I cannot leave the topic of machinery in agriculture without reference to other ways in which the farm has profited from development of machines in industry. One of these is rural electrification. Another is the transportation system and communication by telephone as necessities for marketing. Without belaboring the point, for each of you grasps it in his individual way, the advances here again are in electrical generating machinery, diesel electric systems

for trains, and in the ever improving telephone. By these means the remoteness of the farm has disappeared.

In this farm magazine as well as in many others of a general type, almost every advertisement is for farm machinery.

This has chiefly been about classical physics and agriculture. Now I will turn to a part of modern physics that deals with atoms and molecules. I must admit that I am more at home here for the period from 1920 to 1940 during which I received my training in science and started work was the heyday for this advance. It first should be said that the benefits to agriculture are possibly still minor -- I don't have to misrepresent the subject. But the time is yet young, a hundred years is not so long a time, and the shape of a ponderous thing like agriculture cannot be changed overnight. There are too many social questions involved.

Here I will talk a bit about instruments, about clay, about photosynethesis, another use of light, and about fertilizer. But first I will have to tell you a bit about the advance of physics since 1900.

Near 1900 two essential advances were made in physics. One was the discovery of the electron by J. J. Thomson and the other was the formulation of the quantum theory by Max Planck. These were soon fused with Rutherford's experiments on the low stopping power of matter for fast atomic particles into the concept of a planatary atom. The atom, of nitrogen for instance, has a highly positively charged nucleus that accounts for most of the mass of the element, but the diameter of which is only the order of 1/10,000 that of the atom. Concepts of this atom were being refined as late as 1925 and it was brought to a highly satisfactory state for explaining many facts of spectroscopy, chemical binding and the such, that is with the emission and absorption of radiation by the atom which were the chief means of its study. But there were difficulties. These might be said to be chiefly mathematical in that the basic theorems were not mutually compatible, a type of study that is always before physics and mathematics. For instance, according to classical physics an accelerated electron necessarily radiated energy, but in the atom the electron was thought to be under constant acceleration without radiating.

In the period near 1925, Duke de Broglie in Paris and Shroedinger in Zurich made the essential step of showing that the difficulties were overcome if the electron was described by a wave equation. With this advance the physicist, for the most part, lost interest in what might be called atomic and molecular physics, which then to him was essentially a complete subject. Rather, he turned to the largely unknown question of the nature of the nucleus, which we will cursorily consider later.

Let us consider the electron a bit more. J. J. Thompson's discoveries were joined with the finding of Hertz on oscillating charges and the finding of Edison that hot wires emitted electrons to give the screen grid vacuum tube of De Forrest. From this came the electronic industry and a wealth of apparatus for use in chemistry and in scientific work of agriculture. The pH meter, which is used to measure acidity of soil, is such a valuable, if minute, by-product of this advance.

Knowledge of the electron, particularly of its wave like characteristics, that is -- atomic physics, lead directly to a different type of instrument. This is the electron microscope, the creator of which Marton, then in Brussels, is now working at the National Bureau of Standards on other aspects of electron optics. The electron microscope is of immense value in extending the definition of objects by scattering of waves a thousand fold beyond that of the optical microscope. In this way, the shape of many things of less than so-called microscopic dimension have been found. Important among these are plant and animal viruses, on which progress of knowing their nature has been greatly hastened. Tobacco mosaic virus is in roots that reorder into crystals, vaccinea virus is in tadpole like bodies, bacteriophages are of known shapes.

Although it was not my purpose, I seem to have been diverted by the pH meter and the electron microscope into the question of instruments. Physics in the minds of many stands for precise measurement, but be the measurement precise or approximate, it can usually best be made with an instrument of sound principle in physics. All land measurement, temperature, water flow and passage of time, is made in these terms.

I will avoid a discussion of the variety and complexity of instruments as these were avoided for machines. Rather, a single further instrument will be considered -- the spectroscope. In the first place, the spectroscope or grating instruments for dispersing light serving the same ends have played an immense part in the development of physics itself -- both on the atomic and astronomical scale. It was the spectroscope, in part, that gave the information on radiation from a body at a high temperature that led Planck to formulate the quantum theory. Then the spectroscope was used for measuring the frequency of radiation emitted by excited atoms, and so-called spectrum lines. Attempts to account for the ordered sequence of these lines in frequency resulted in the development of atomic structure. Light emitted from an atom as analyzed by the spectroscope characterizes the environment of the atom. In the hands of the astronomers this has led to knowledge of what is going on in distant stars that far exceeds what is known about the earth below a depth of a few miles.

The spectroscope was early adopted by the chemist and in his hands was used for the discovery of elements. It was also refined and simplified to become a routine laboratory instrument for the identification and measurement of such compounds as carotenoids and other plant pigments as well as haemoglobin, vitamin C, and cytochrome C in animals. I doubt if you could go into an up-to-date laboratory devoted to agriculture without finding a spectrograph in use. They are the integral part of the flame photometer with which the soils man measures potassium. With it he also quickly assays for sodium in alkali soils and brackish waters.

Would you care to contemplate the task of mapping for agriculture, be it of soils or of land units, on the basis of what was available in 1900? The difference in mapping between 1900 and now is in physics, including the physics of the conquest of flight as well as in increased knowledge of optics. The camera, which is basic to mapping, compounds physical optics with inventive ingenuity and technical advance in manufacture.

There is an immense variety of instruments developed from pressure of the last world war that will prove of value to scientific work in agriculture.

These still await introduction for the most part. To mention one fancy case, Dr. Shaw of the Western Regional Laboratory, Agricultural Research Service, made very effective use of nuclear resonance in assessing the importance of bound and free water in quick freezing and dehydration of foods.

The instrument in the laboratory extends the effectiveness of a scientific worker in agriculture just as much as the machine in the field aids the farmer. Both are Physics.

Another advance in what might be termed atomic physics, the physics of 1900 to 1925, has to do with X-rays. The discovery of X-rays by Routgen was an incident in the study of the nature of electric discharges in gases. Its benefits to medicine are known to all of you. But it has also benefitted agriculture by coupling with another discovery, that of diffraction by crystals. This second discovery was made in 1912, some 15 years after the first, and by 1920 it had been developed into a subject, the determination of atomic arrangements in solids. Through the determinations that have been made, the structure of essentially all silicates are now known. The silicates are the minerals from which the earth, including its soils, are formed.

The important minerals in soils are clays and even the vaguest understanding of why a soil might have its observed properties required knowledge of the clays. This was gained for a considerable part by X-ray diffraction. It is now an essentially completed subject and from it, for example, there is an understanding in detail to the behavior of potassium in soils.

There is another more recent result of X-ray diffraction that bears great promise not only of incidental benefit to agriculture but might supply an entering wedge for the understanding of a basic mechanism of life. This is the determination of the structure of desoxy ribo nucleic acid which reveals it to be in the form of a double belix. This compound is an essential part of all the reproducing structure mechanisms of life, of chromosomes, of phages, and of viruses. At this time there is great activity aimed toward knowing also the structure of the related ribo nucleic acid and of all proteins, including such things as haemoglobin.

We are at the threshold of immense potential advances in biology, in an understanding of life that cannot do other than benefit agriculture in such things as disease resistance and the general basis for breeding. Physics is and will continue to play a very significant part in these mainly biological advances.

Now I had better return to energy and its conversion. While the farmers have their many pressures, some surely stop to consider the part that the sun and green plants play in their lives. Now the physicist seeks to understand the sun and what happens to sunlight on the earth. One thing that happens to the energy represented by sunlight is that it supplies the energy for growing plants from which animals, including ourselves, draw their energy. Thus, we arrive at photosynthesis.

It should be remembered that photosynthesis supplied the fossil fuels, coal, oil, and gas, that run the machines. In short, this has been an effective method for storing energy from the sun for a future use. This took place over a long period so that in a sense the present age is living off accumulated reserves, that are limited. Naturally, then, some attention is given to thoughts of replenishing the reserves, or running on a more balanced scheme. The

physicists then, and we must admit a lot of others of various shades of information, give attention to the question of storing solar energy or of converting it effectively into more usable forms of energy. The physicists' method as far as photosyntheses is concerned is to understand if possible how the energy transformation from radiant to chemical energy is effected.

The chemical end of this transformation now is much better known than the part with which physics deals. Through the work of Calvin at the University of California and of Horecker at the National Institute of Health in Bethesda, the pathway of carbon dioxide in photosyntheses has been established. In short, this is the addition of carbon dioxide to ribulose 1,5 diphosphate with breaking into two three-carbon compounds. The energy source has to supply energy for formation of two molecules of adenosine triphosphate and one molecule of diphosphopyridine nucleotide for each molecule of carbon dioxide fixed. These names of compounds, if they are unknown to you, might at least serve to emphasize that much is known.

The portion of the radiation from the sun that is visible to the eye only is used in photosynthesis. This is absorbed by the green pigment, chlorophyll, in leaves of plants. So now the radiant energy is present as excitation energy of chlorophyll. The chlorophyll is present in small clumps or grana in which one molecule is in close association with several other substances, including the yellow pigment carotene. In the grana the energy is passed from one molecule to another and finally arrives at a specific place. Here things black out; what happens to the energy of the chlorophyll at the specific place is unknown — the gap is from here to the adenosine triphosphate and diphosphopyridine nucleotide. It is known that hydrogen is taken from water with evolution of gaseous oxygen.

The physicist is not so charmed by the nature of photosynthesis as to forget a primary concern with conversion of radiation solar energy into other forms of energy by whatever means possible. To this end, solar heaters of various types and arrangements of houses are being developed. These don't seem to threaten photosynthesis as an easier method for the energy conversion. Possible development of solar batteries and possible in vitro photoreactions are potentially more promising.

Photosynthesis is not the only way in which plant life depends upon radiation from the sun. There is another way that controls the shape and reproduction of the plant — that is a marked factor in the persistence of weeds. Here, too, physics gives a hand to an essentially biological subject. The way in which an understanding of flower formation and seed germination control has developed has depended largely upon the spectrograph or equivalent physical devices. These are the self same instruments that were mentioned earlier as playing so important a part in the development of physics itself. With the light of various wave lengths isolated, the action of this light permits me to unravel some of the intricacies of the flowering control.

Let us say that a bind weed seed lies half an inch below the surface of the ground. It might have been there for fifty years without germinating beneath a sod. Then, one day the sod is turned over with a plow — the seed germinates. The reason is that it first is exposed to light. What is more important then than to find out how this works? What more direct than to study in detail how the light acts? Here the biologist and the physicist team up. The unexpected result is that flowering control and germination control cooperate through the same mechanism in plants.

In such matters as the persistent bind weed seed, one looks back toward the philosophical matters of science that were so important to the Greeks. Here the matter is that an observation is made, a practical observation; the philosophical point is that a cause can be sought. There is no blind acceptance of untried explanations. Physicists and mathematicians have been at the forefront of philosophical advance in sciences. In this regard, they have aided biologists and have fused, in part, with chemists. Rather one might say that the physical sciences are closer to their philosphical backgrounds and from this closeness support the biological sciences to seek similar ends.

Photosynthesis and other light reactions of plants work on radiation from the sun. The more primitive question is where does the energy of the sun come from. The answer is in nuclear reactions between carbon and hydrogen that are going on in some region near the center of the sun. This brings us naturally to energy derived from nuclear reactions -- atomic energy if you will.

As far as agriculture is concerned, interest in atomic energy really rests in the fact that it is energy. In the production of the energy there is a product or byproduct, namely radioactive materials. Scientific agriculture has turned these radioactive materials to good use, but to date nothing has been done in agriculture with the power. Later, I will discuss these uses of radioactive materials. But with this promise of returning to my subject, let me turn instead to the intellectually interesting question of what atomic energy is and how the physicist found out about it. The Smyth Report is a good introduction to the topic. Another book is "Atomic Energy" by Glasstone, which is published by D. van Nostrand Company.

Two immediate basic discoveries upon which development of nuclear energy depend were made shortly after 1900. The first of these was that atoms have nucleie. As was mentioned earlier, this discovery was a result of noting that high energy particles readily penetrated matter as if these were very transparent. This observation soon was interpreted as indicating that the mass of atoms was chiefly carried by nuclei having distances of interactions with other nuclei of the order of 1/10,000 of the distances between atomic centers in soils. This is just about the relationship of the earth to the moon, with space in between that has a certain probability in the case of the atom of being occupied by electians.

The second advance was the special theory of relativity from which came the fundamental relationship for the equivalence of mass and energy, namely

$$\text{Energy} = \text{mass} \times C^2$$

where c is the velocity of light. This was due to Einstein. To some this might sound like equating rabbits and oranges, but it should be realized that the equation is dimensionally correct. The equation states that a certain mass can be converted into energy. The square of the velocity of light is an immense figure, 10^{21} cms/second, to be exact. Thus, 1 gram, 1/28 an ounce, of matter converted into energy gives 10^{21} ergs or about 2.10^{13} calories. This is enough energy to evaporate 3×10^{10} grams of water which is about ten million gallons.

For the next twenty years while most physicists were working out the explanations for atomic phenomena, a few, notably associated with Rutherford at Cambridge University, England, plugged away on the nucleus. By 1925 not too much was known, but the philosophical nature of the advances that wrapped up atomic physics set the stage for advance on the nucleus. Two real breaks came in 1932. The first was the discovery of artificial radioactivity by Pierre Joliet and his wife Irene, the daughter of Madame Curie, who with her husband, Pierre, had developed the understanding of radioactivity and discovered radium. This was the experimental evidence that atoms could be changed.

The second discovery was the neutron, made by Rutherford's colleague, Chadwick, as a result of the same observations that inspired the work of the Joliets. To discover a new particle is a marked advance in the understanding of the ultimate structure of matter. The neutron is characterized by a mass near that of hydrogen and has no charge. This last is important for, due to the absence of charge, the neutron can more readily approach nuclei of atoms, these having a high positive charge.

In 1939 the discovery that directly led to development of nuclear energy came in this sequence of discoveries. It was of atomic fission by the entrance of neutrons into the uranium 235 nucleus. The discovery was due to Leisa Meitner and Otto Hahn, then in Sweden. There observations were quickly repeated and extended. I recall the first colloquium and experiments here in Washington on the subject -- the colloquium on a January night was attended by just ten people. Can you wonder that some of us pass the facade of the Atomic Energy Building on Constitution Avenue and ponder about these things.

The use of atomic energy, that is, the release of energy by the entry of neutrons into some heavy atomic nucleic, finally resolves itself into a question of heat transfer. The nuclear reactions can be controlled so that they are not explosive and the reactions can be run at any desired temperature. But the nature of containing vessels and heat transferring liquids is difficult. These things are being overcome now, such that power costs are within an order of magnitude surely less than a factor of ten in the United States to that in the usual steam plant.

In the production of power or of plutomium, the nuclei of the fuel element are split with the production of radioactive fission products or neutrons in the reactor can be used to activate the induced radioactivity of other elements such as carbon phosphorus or potassium. As of this time, it is this radioactivity that is of most use in agriculture.

The radioactivity is used in one of three ways. The first is as penetrating radiation like X-rays, the so-called gamma radiation. The second is as less penetrating electrons or beta rays. The third is as the radioactive elements themselves acting as tracers for the same non-radioactive elements; that is, as isotopic tracers.

These uses of radioactivity which I will shortly illustrate are similar from the point of view of physics to instrumentation. Although they are different in kind, they are comparable with the use of a microscope or with the development of an electron microscope. They are essentially tools for agriculture that might continue to be used in the hands of agricultural scientists.

An illustration or two will be taken from each of the three parts. First is of penetrating radiation, gamma rays. The illustration is the use of a source of gamma radiation such as the cobalt isotope of mass 60 and of a portable detector to measure the density of matter between the two. This is being applied to measurement of density of soils in the field, of their water content, and to the flow of bagasse in sugar mills, The radiation as such can be absorbed by living germ plasm without destruction of the organism to produce sterility or chromosome modification. These uses, of course, are still minor to the whole subject to which they are applied.

The beta radiation bears some promise for sterilization of agricultural products against microbial action. The hope is that sterile systems can be achieved without the use of heat and its concommitants. This might be achieved. There is a lot of pressure on it as a topic for development because the development of power reactors is tied up with the by-product of intensely radioactive materials. Some satisfactory results have been obtained and the question is as to their practicality. In general organisms are easier to kill than enzeymes are to inactivate.

Isotopic tracer use is on a more secure footing of success in agricultural research. The most important result to date is that afforded by the use of C14 in following the course of carbon dioxide fixation in photosynthesis. Without the carbon isotopes C14, C11, or C 13 the problem was too difficult of solution for the compounds involved were too transient and too dilute for detection by previously available methods. The course of carbon dioxide which was mentioned earlier was of an unexpected type at every turn.

A second successful use of these radioactive materials has been made in tracing mineral nutrient utilization by plants. Crudely spoken, this is in the agronomy of fertilizer use and in measurement of soil fertility. Phosphate tracing has been the most fruitful to date, because of its characteristics and the very suitable radioactive isotope that is available, namely the phosphorus isotope of mass 32. It affords a direct measure of the degree of utilization of a particular phosphatic fertilizer by a crop. This is important since previously crop yield only, which is an extremely indirect result, could be used for fertilizer evaluation.

Nuclear energy for the time though is synonymous in the public mind and in actuality with what is called the atomic bomb. This is perhaps the most striking and significant result of the last world war. It is credited with terminating at least one phase of that war. The first world war too had its significant result in the culmination of an advance in physical science, namely the fixation of atmospheric nitrogen. The success of the Haber process for catalytic combination of nitrogen and hydrogen at high pressures is considered to be the sole reason why Germany could continue the war from 1916 to 1918. But the process is effective not only as a source of nitrogenous compounds for explosives, but also for fertilizers. Over two million tons of nitrogen are now fixed annually in the United States. This is a tremendous quantity and with machinery is one of the factors that has most modified American agriculture.

Fixation of a ton of nitrogen though takes a lot of energy; otherwise, the nitrogen and hydrogen are abundant. The physicists, aware of man's rapid utilization of fossil fuels, has given thought to this factor for production of nitrogen compounds. Specifically he is aware that at equilibrium on the earth the sea should be tenth normal nitric acid. The only question is to get a

process that moves toward equilibrium for nitric acid production in a controlled and effective way. Again the problem can be solved in principle. The practical attack has been to effect the thermal combination of nitrogen and oxygen in the region of 2000°c and quench the product. If all the difficulties of materials to withstand the necessary conditions are overcome this might be the real way in which nuclear energy might serve the needs of agriculture. Here the problem is first a source of heat at 2000°c and second, the scrubbing out of the gases.

The physical scientist is interested as much in what causes the low activity of the nitrogen of the atmosphere and still permits its reaction by bacterially controlled processes in legume roots. This is in part a question of atomic physics, of how to excite the nitrogen molecule.

You might wonder from all this as to how what might be called work-a-day physics gets along in agriculture. Very few physicists are employed in agricultural work, say the order of 100 in the entire United States. Of these, not more than twenty are in the U. S. Department of Agriculture and not more than three are in the large research group at Beltsville. These physicists in Agriculture are chiefly concerned with instrumentation or with the behavior of water in soil.

The great advances that influence the true course of any subject like agriculture or medicine seldom are immediately associated with these objectives, which after all are applied. Instead, they come from basic or fundamental science. The work-a-day aspects of physics might just as well be devoted to physics. In agriculture it might be best to maintain a high level of awareness of what's going on so that the day of eventual change will not be delayed. This can be done, and is being done, in part by having a fair attitude toward all fundamental research. A dozen obvious fundamental topics, however, could readily be pointed out that merit support within agriculture far beyond what is now accorded.

THE SIGNIFICANCE OF PROGRESS IN FOOD PROTECTION TO AGRICULTURE*

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The term "Food Protection" may not be overly specific. Conceivably, it could refer to protection of growing crops by use of pesticides; or to food packaging methods, or storage facilities; or to food preservation processes. It could even refer to the kind of protection needed by, say, a watermelon patch owner in a neighborhood of small boys. I have some first-hand knowledge of that particular problem--but I long ago classified it as "restricted, in the interest of security of small boys."

The connotation I here propose to give the term "Food Protection" is in reference to accomplishment of regulatory measures directed toward fostering safety and wholesomeness in food, and honest representation of food commodities.

Often these measures are characterized by the phrase "in the interest of consumers." Of course, they are--but they are by no means exclusively so. If you had happened to have observed from the program that I represent the Food and Drug Administration, you would perhaps have suspected that I might undertake to associate agricultural welfare with food law enforcement. And in that case you may be here largely out of curiosity--as to what one might say, favorable to food law enforcement as an aid to agriculture. For I would not deny that the immediate impact of a specific instance of food regulation may sometimes pose added problems, rather than provide solution to problems already facing the agriculturalist. In the broader view, however, I think it can be demonstrated that food regulation has a significant value to agriculture--a value akin, in some respects, to fire-and-theft-prevention measures.

The Federal Food, Drug and Cosmetic Act is, of course, a prominent instrument of food protection--in the sense I intend. It is by no means the only such instrument, nor is it our only "Pure Food Law," despite its popular appellation. To name others, there are the Meat Inspection Act and the Agricultural Marketing Act, both administered within the Department of Agriculture; and statutes under jurisdiction of the Federal Trade Commission. All are forceful tools of food protection. To these, add parallel activities by and within the States, and by counties and municipalities. Finally, prominent recognition should be given non-governmental self-regulation by agriculture and by the food industry in general. It is of all such as these, and their joint influence, that I speak in postulating that organized regulation of food production, processing and distribution is of significant benefit to agriculture

Food sophistication, mishandling, and misrepresentation are as old as commerce itself. One of my associates had made a study,(1) more or less as an avocation, of incidents of recorded history concerning food adulteration and steps taken toward its mitigation. The dietary laws originating in antiquity are, of course, a type of regulatory measure. Other means of

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(1) Hart, F.L., Food, Drug, Cosmetic Law Journal 7 no. 1, 5 (Jan. 1952)

food control are mentioned by ancient scribes, notably in recording governmental decrees prescribing punishment for those apprehended in commission of antisocial practices. Severity of penalties contemplated often suggests extreme aggravation of offenses perpetuated--and perhaps reflect the reaction of thoroughly imposed-upon consumers and competitors.

Toward the end of the middle ages, the record gives clear indication that the food trade itself was assuming initiative in control of its fringe members--apparently with prime objective to suppress disruptive trade practices, rather than in direct concern for consumer interest. This trend gained prominence in England as early as the twelfth century, with the formation of guilds, Such commercial organizations were often accorded functions we now regard as within the province of government. One of the earliest and most prosperous of the food guilds was that of the "Pepperers." They expanded and in time took in the grocery trade generally. The British Crown made them custodians of the official Weights Standards, and appointed official weighers from among their membership. Within the guild was established the profession of "garbeler," a title which stems from an old Arabic word meaning to sift or select. Garbeling was the process of detecting and removing impurities and adulterants from spices and similar products, and certifying to their commercial purity. In practical effect, the garbelers were the first public food inspectors of England.

During these times, history continues to record instances of most drastic punishment for food adulteration. On the continent, in 1444, an adulterator of saffron was burned at the stake over a fire of his own saffron. Since this spice was, and is, relatively expensive, it must certainly have been a grossly spurious product that served as fuel. More significant, though, seems the probability that impetus to such severity could hardly have come solely from exasperation of a handful of competitors; the fury of an aroused populace is stronly suggested.

There has then long been evidence of alternate yet related motives for food regulation--consumer interest on the one hand, and suppression of demoralizing competition on the other. It seems hardly possible that these objectives have ever been wholly divorced, even though, at different times and in different places, the one may have been vastly emphasized in relation to the other.

We can readily recognize these twin motives in the background of our own food regulation measurements. Pertinent to this point is the observation that Harvey W. Wiley, who became known as the "father" of our national pure food laws, was, for twenty-three years prior to their enactment, Chief Chemist for the Department of Agriculture. Even so, and contrary to beneral impressions, he did not himself start the movement, within the Department, that culminated in this legislation. For at least two years prior to his appointment in 1883, the Department had been conducting studies on food composition and its adulteration. Wiley did accelerate the pace of that investigation and he occupied an increasing proportion of his staff in its pursuit. The Department lent gratifying support to his objectives, not only in the investigational stage prior to the turn of the century, but also in the six years thereafter that saw the active struggle for effective national food regulation. In view of the basic obligation of the Department to further the interests of agriculture, it seems apparent that many prominent and well-informed friends of agriculture must have shared with Wiley the expectation of agricultural benefit to accrue from comprehensive food control.

The first food law enacted in this country had been that of the State of Massachusetts, in 1784. In the course of the following century, most of the States had undertaken to regulate the food traffic in some respects. With certain noteworthy exceptions, a characteristic of these laws was an emphasis on discouragement of trade practices harmful to the general commerce. Consumer interest was not necessarily ignored; no doubt there was expectation of consumer protection in consequence of regulation of competition.

Little uniformity existed in provisions of the various State laws. That fact alone impared their effectiveness to the point where their failure, generally, became conspicuously apparent, and the more progressive State food law administrators gave increasingly active support to the movement for national legislation, as the only hope of rendering the regulatory effort effective.

During the some seventeen years of study that Wiley and his associates devoted to the investigational phase of their campaign, they had before them ample evidence of the practical accomplishment, or lack thereof, of control measures already in effect. That national legislation would go far to correct for non-uniformity was evident. Not so apparent was the improvement to result from shifting emphasis of the regulatory approach toward the direction, primarily, of consumer interest. Yet the provisions that Wiley and his backers in the Department settled upon, and fought to have enacted, were predominantly so characterized.

Admittedly, one may not attribute, wholly to that approach, the recognized success of the national pure food laws. But the fact remains that emphasis on consumer interest is a salient aspect of a mode of regulation that has succeeded, to the benefit of agriculture, the food industry, and consumer alike, over a period now of almost a half century.

Benefit to agriculture from consumer protection is perhaps not demonstrable by direct methods of proof. But it may be shown in the same way that the value of insurance is made evident--and my listeners, I am sure, are familiar with the way an insurance agent goes about that. Just as he points to the consequence of disaster when insurance coverage is lacking, so may the effectiveness of food regulation be illustrated by citing consequences of its failures.

Such a failure occurred in the period around 1920, in connection with the relatively rare food poisoning known as botulism. This is due to an anaerobic bacteria that develops an exceedingly virulent toxin under conditions favorable to its growth--such as those obtaining in low acid canned foods that have not been adequately sterilized. In August of 1919, near Canton, Ohio, 14 individuals suffered acute illness, and seven of them died of botulism, reliably traced to a single jar of ripe olives, some of which each victim had consumed(2). Within the year an outbreak of botulism near Detroit, attributed to the same brand of ripe olives, claimed 5 more deaths. Nineteen further botulism deaths, in scattered locations, attributable to ripe olives, occurred between 1918 and 1921, and an additional eight in 1924.(3)

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(2) Armstron, Chas., Story, R.V., and Scott, E., Public Health Reports Dec. 19, 1919, p. 2877 (Reprint No. 577 USPHS)
(3) Meyer, K.F., and Eddie, B. - 50 years of Botulism in the U.S. and Canada, Geo. Williams Hooper Foundation, July 1950.

Botulism had by no means been previously unknown; but it had occurred relatively more often in connection with home-canned products rather than those commercially produced. Moreover, it had not been theretofore attributed to olives, let alone those in the channels of trade, as was the case in each of these instances. Consequent widespread publicity, particularly that attendant on the Ohio and Michigan outbreaks of 1919-20, was highly damaging to all olive packers, not only those who may have been culpable, and almost ruined the then young and expanding California ripe olive industry. Production dropped 50% within the two years following the Ohio incident. After 1924, it dropped off again by more than 40%. I am sure there are those in my audience who remember the general aversion of the public for ripe olives, persisting for many subsequent years.

Correction of conditions giving rise to these poisonings was fraught with difficulty. Obviously the process had to be made perfect; a single ineffectively sterilized can, out of the hundreds of thousands packed, even under diminished rate of production, could impose further irreparable damage on consumer and producer alike.

I have said that non-governmental self-regulation by agriculture and the food industry is to be accorded prominent recognition for its contribution to progress in food protection. That recognition is particularly well merited in this instance. The olive industry, with technological support from such organizations as the Hooper Foundation and the National Canners Association, cooperating with the California State Board of Health and the U. S. Bureau of Chemistry, worked these problems out. Moreover, they did so with a breadth of consideration for the technicalities of all canning, such as to measurably advance development of the system of regulatory control of cannery operation that makes the California State Cannery Inspection Service today a pattern copied throughout the world. Since 1925 there has not been a single outbreak of botulism attributable to domestic olives. Moreover, from any of the many domestic commercial products potentially favorable to development of the toxin, canned in enormous volume, there have been but four botulism outbreaks since 1925, involving only three deaths. I would not wish to appear callous of even a single death--or a single illness--from food poisoning, but I do submit that this country's record in this respect, for more than a quarter century, is indicative of real progress in food protection.

The most recent outbreak of botulism, occurring in 1951, involved a dairy product familiar on every grocer's shelf. Some time prior thereto, the Food and Drug Administration had initiated an operating procedure that has come to be known as a "recall." It is a cooperative effort, jointly by the distributor of an article and all needed agencies of food regulation, monitored by the Food and Drug Administration, with objective to remove from availability for consumption all outstanding units of a product that may be imminently dangerous to health. Full concurrence of the distributor is, of course, prerequisite to practical invocation of a recall. It has proven so effective, and so mutually beneficial to producer and consumer, that we have come to experience whole-hearted cooperation from distributors in virtually every instance we have regarded as meriting a recall.

That was true in the case of the 1951 incident involving the dairy product I speak of. Not only every package of the suspect batch, but so far as we know, every unit of this brand of the product, anywhere in the

country, was withdrawn from the market within a very few days. Contrast this with the 1919 outbreak, if you will: At that time, some of the same brand of olives remaind available to the consumer for at least the better part of a year, taking five lives more than would have been lost had an effective recall been instituted.

Many samples of the dairy product I mention were subsequently examined, with the finding of only one more contaminated package. Not all, of course, of the many thousands of recalled packages were tested; whether there could have existed, among them, further lethal units, is practicably undetermined with absolute assurance. But from the olive disasters of the twenties, one may realistically speculate what might have been the impact, in 1951, on producers, in general, of this type of dairy product, had only a few more toxic packages reached the consumer--and, in turn, one may well ponder the consequence to welfare of the dairy segment of agriculture.

These incidents illustrate certain aspects of advance in food protection, significant to agriculture. Pertinent illustrations are by no means as rare as is botulism, nor are all occasions for exercise of regulatory measures as acute. Day-to-day food regulation is far less colorful, but, in the aggregate, far more significant than the spectacular and readily describable examples with which it is possible thus briefly to deal. It is the routine administration of food protection measures that in the long run safeguards the confidence of the public in the nation's food supply; and every food producer must acknowledge the incontrovertible fact that it is public confidence in his product that is the source of his economic welfare. Moreover, in view of the virtually revolutionary change in modes of food preparation, packaging, and distribution that has occurred in even recent years, evident in a growing multiplicity of ready-to-heat and ready-to-serve food products, effective routine of food regulation today is quite likely to be the regulatory innovation of only a short time earlier. Hence there is evidence of progress in food protection in the fact that regulatory measures have been able even to maintain a status quo, let alone advance public confidence in our food supply.

This progress has been dependent heavily upon the contribution of the food chemist, both those of official agencies and of the food industry, in providing reliable methods of food examination and analysis, for the many new needs associated with these changes in character of the food supply.

The early day British had an official food chemist of sorts. He was the "ale-taster."(4) He had the obligation, in terms of a fifteenth century law, to "try, taste and assize the beer and ale to be put on sale." His methods of trying and assizing were liable to be somewhat empirical. They came to include a test whereby he poured some of the ale on a wooden bench and sat on the wet spot in his leather breeches. If his posterior stuck to the bench, the sample failed to pass the test. That might seem to be going about it backwards, but we now know, of course, that adhesive properties of ale are most likely due to unfermented carbohydrate--hence the test might have validity to expose an unsound brew. Our procedures today are substantially more objective.

But they were not very much more effective at the time the Department initiated its studies of food adulteration. As is now well recognized by those in the profession, analysis was for a long time an unduly neglected branch of chemistry, even relegated by many to a status beneath the dignity

(4) Hart, Loc. cit.

of scientific work. Wiley, in an early Department Bulletin,[5] has said of methods of analysis in use in 1880 that their condition was truly chaotic. "There was no standard of comparison or reference. Buyers and sellers were continually wrangling over analyses, which, made by different men following different methods, did not agree."

The first steps toward alleviating this condition were taken through the initiative of J. T. Henderson, then Commissioner of Agriculture for the State of Georgia. By his solicitation, a convention of Agricultural Commissioners and Chemists assembled, on July 28, 1880, in Library Hall of the Old U.S.D.A. Building that formerly stood just across the street, Henderson had invited his colleagues to meet for the purpose of considering adoption of a uniform system of fertilizer analysis. That there was need for concern in this regard is amply demonstrated by collaborative results reported on check samples distributed during the following year among several of the chemists who had attended the convention. Findings in different laboratories, on the same sample, even when obtained by what was regarded as the same method, varied by as much as several fold. The collaborating chemists were not considered unskilled, by standards of the time; on the contrary, they held various positions of responsibility for conducting analyses in enforcement of State laws, and for certifying to the composition of products commonly dealt in commercially on that basis. It was clear that the methods they used were unequal to the needs of quantitative analysis.

In pursuit of improved methodology and unification of analytical practice, they held further conventions, from time to time. It was on the occasion of the fifth of these, in Philadelphia, in 1884, that the Association of Official Agricultural Chemists was formally established, with Wiley as its first president. It was dedicated to securing uniformity and accuracy in methods and results of analysis. From a modest beginning on studies of methods of fertilizer analysis, the Association expanded its scope of interest to include stock feeds, soils, caustic and economic poisons, drugs, cosmetics and coal-tar dyes, as well as all types of food.

One could not, by any means, claim, for the A.O.A.C., sole credit for the tremendous advance that analytical chemistry has made since 1880. Nor would my regulatory colleagues suggest that they alone are responsible for the bountiful contribution of the A.O.A.C. to improvement of methods of food analysis. But they do take justifiable pride in the fact that it was chemists in regulatory capacity who pioneered in the effort to establish reliable analytical methods; and that those responsible in variant ways for food protection have consistently sustained and advanced that effort to its now comparatively adequate status. True, this has been of necessity. Technologists in few other fields face the obligation to insure that their daily work be of a reliability meeting a test so severe as that of cross-examination in a lawsuit. It is no small responsibility to render an official analysis in full confidence that will not improperly furnish basis for condemnation of property, and yet will not fail to disclose adulteration hazarding public health or otherwise imposing on consumer rights. There yet remains much to be done, but that we are today vastly better equipped than formerly, and that constant improvement is being accomplished in our methods for objectively effectuating food-protection measures seems to me not only significant but gratifying to agriculture and consumer alike.

(5) U.S.D.A., Div. of Chemistry Bull. 57, 16 (1899)

Associated with development of analytical methodology has been a parallel development in food standardization.

Foods acquire identity in various ways, but basically the concept of identity of a specific food originates in subjective response to its form, texture, color, odor, and flavor. In the simplest case--that of the immediate product of agriculture--the botanical scheme of classification--by genus, species, variety, etc.--furnishes a ready means of translating the subjective concept of its identity in terms of objective expression. The identity of a compounded or manufactured food, if it has attained a recognized identity, may be partially defined in terms of its components, and their proportions. But this often does not suffice. As everyone knows, bread, for example, is not fully defined by a list of its ingredients; bread exhibits additional identity characteristics, readily perceived, but not so readily described. Even so, it is not identity, but quality, that normally presents the greater difficulty to standardization. For quality usually depends wholly on the product's stimulation of subjective impressions--for which there exists no classification scheme, handy to objective expression.

It is essentially for these reasons that food standards are needed--to provide a common basis of understanding between buyer and seller, to the end that the identity and quality of a product in channels of commerce may appropriately be related to its sales price.

The primary goal, and the prime difficulty, in developing food standards, is to translate subjective considerations in terms of objective reference. It is commonly difficult, if not impossible, to convey directly, in words that all will equally understand, those nuances of appearance, texture, bouquet and flavor, that may contribute to identity and almost always make for quality. Various means have been adopted for practical circumvention of these limitations of language. One of the happiest of such means is illustrated in the instance of canned peas. In developing the Federal minimum standard of quality for that product, it was recognized that quality of peas is predominantly related to their harvest maturity. Hence a measure of peas maturity might be expected also to serve as an index of prominent quality factors. That has proven to be the case; alcohol-insoluble solids content, measuring starchiness, which increases as maturity advances, serves reliably to reflect principal facets of canned pea quality.[6] Thus a wholly impersonal measure is employed to gauge these highly subjective attributes. We have progressed far in standardization of food products, to the end of regulating competition in the interest of both producer and consumer. In achieving that progress, we have, of necessity, depended heavily on subjectivity in framing of standards. It seems evident that standards so framed have at least the potentiality to exhibit, in application, a tendency toward elasticity. Granted that such rubber yardsticks are better than none at all, and that they may practicably serve their purpose if used with due recognition of their defect, yet they are not the best to be desired. For the advantage of relative certainty that objectivity contributes, the present trend of food standards in that direction represents a development as significant as was the initiation of the food standardization movement many years ago.

In summary, modern measures of food regulation, on a unified national scale, are oriented to emphasize consumer protection. This approach, if

(6) Lee, F.A., Whitcombe, J., and Hening, J. C., Food Tech. 8, 126 (1954)

successful, will obviously serve to foster and maintain public confidence in the nation's food supply and thereby to safeguard agriculture's market. Improvement of regulatory operating procedure, progress in development of reliable methods of food examination, and in formulation of increasingly objective food standards, have been instrumental in maintaining and advancing food protection accomplishment. Gratifying contribution of agriculture and the food industry to over-all effectiveness of this effort, seems indicative of general recognition that, in the long run, interests of consumer and producer coincide.